PROCEEDINGS

of the

American Society

for

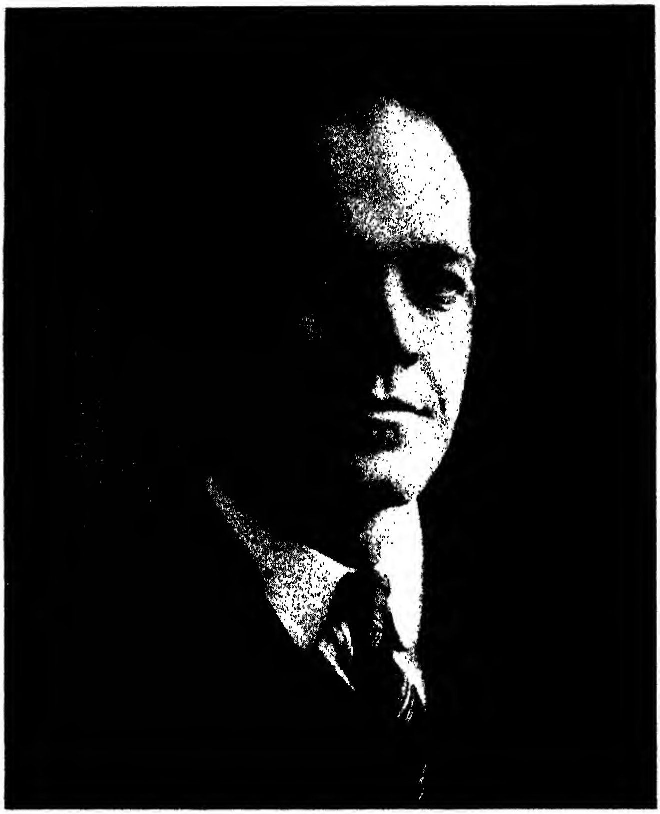
Horticultural Science

for

1933

Volume 30

THIRTIETH ANNUAL MEETING



LAURENZ GREENE

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AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

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1933

Thirtieth Annual Meeting

Cambridge, Mass.

December 28, 29 and 30, 1933

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Secretary-Treasurer .... H. B. Tukey
Assistant Secretary .... F. N. Fagan

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G. T. Nightingale (1935)
J. H. Gourley (1934)
Roy Magruder (1937)
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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, three Vice-Presidents, and a Secretary-Treasurer, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. There shall also be an Assistant Secretary. These officers shall be elected annually by ballot.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this Committee, at the following meeting, to suggest to the Society nominees for the various committees, and one nominee for each of the offices for the ensuing year.

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC. 4. The committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

*The Constitution and By-Laws as amended from time to time.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be four dollars.

SEC. 7. Ten members of the Society shall constitute a quorum.

SEC. 8. There shall be an editorial committee consisting of five members. One member shall be elected each year to serve for five years.

SEC. 9. There shall be a committee on sectional groups and membership.

SOCIETY AFFAIRS

RESUME OF THE ANNUAL MEETING AT BOSTON, MASSACHUSETTS, DECEMBER 28, 29, 30, 1933

The thirtieth annual meeting was held at Sever Hall, Harvard University. There were fourteen sections including a joint session with the American Society of Plant Physiologists and a joint session with Section O (Agriculture) of the American Association for the Advancement of Science. There was also a round table for extension workers as well as a symposium on "Factors Affecting Flowering of Plants." The dinner and social evening was held at the Commander Hotel.

REPORT OF THE EXECUTIVE COMMITTEE AS ADOPTED

1. Additional sections to be added to the By-laws:

SEC. 8. There shall be an editorial committee consisting of five members. One member shall be elected each year to serve for five years.

SEC. 9. There shall be a committee on sectional groups and membership.

2. Upon vote of the executive committee the publication of a second volume of the Proceedings may be authorized, the cost to be borne by those publishing in such volume.

CHANGES IN THE CONSTITUTION

The following amendment, as proposed to the Society at the 1932 annual meeting, was read and adopted:

1. The amendment to Article III, concerning associate members: Associate members—any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

2. The amendment to Article V concerning the election of officers by mail, proposed to the Society at the 1932 annual meeting, was defeated.

PROPOSED CONSTITUTIONAL AMENDMENTS

The following amendments were proposed, to be voted upon at the 1934 annual meeting:

1. Amendment to Article V. Section 1.—The officers shall consist of a president, a vice-president, a secretary-treasurer, and three sectional chairmen to represent the three subject-matter sections of the society. The officers shall be elected annually.

SECTION 2. The officers shall be elected in the following manner: (a) At least three months prior to the annual meeting the secretary shall call for nominations by mail for the office of president, of vice-president, and of secretary-treasurer; such call shall be accompanied by the names of persons who have served as president. The three names receiving the highest number of votes for each office shall be placed on the official ballot to be sent to the voting members at least four weeks prior to the annual meeting. The balloting shall be declared closed one week prior to the opening day of the meeting. The nominees receiving a plurality of votes shall be declared elected.

(b) The three sectional chairmen, the members of all standing committees and representatives shall be nominated by the nominating committee. These officers, members of committees, and representatives shall be elected by ballot at the annual meeting.

PROPOSED CHANGES TO THE BY-LAWS

It was proposed by the executive committee that the following changes in the By-laws should be made in order to conform to the constitutional changes above mentioned, if and when adopted:

SEC. 2. There shall be a committee on nominations consisting of five members, who shall be nominated and elected by ballot at each annual meeting of the society. It shall be the duty of this committee, at the following meeting to present a list of nominees for the various committees and representatives, and for three sectional chairmen, the latter to be chosen in consultation with the sections.

SEC. 3. There shall be an executive committee consisting of the retiring president, who shall be chairman, the vice-president, the three sectional chairmen, and the president and secretary-treasurer, ex-officio. This committee shall perform the usual duties devolving upon such committee.

REPORT OF RESOLUTIONS COMMITTEE

Be it resolved, that the American Society for Horticultural Science extends its sincere thanks to the management of the Commander Hotel for the use of committee rooms, and other facilities furnished to the Society:—

To Harvard University for meeting rooms, attendants, and other services:—

To the officers and committees of the Society for good work during the year, and particularly to the Secretary-Treasurer and the membership committee for their efficiency in maintaining membership under the trying conditions of the past year:—

And to the local committee which has made such satisfactory arrangements for our convenience and entertainment.

C. P. CLOSE, *Chairman*
J. H. CLARK
L. H. MACDANIELS

REPORT OF NOMINATING COMMITTEE AND ELECTION OF OFFICERS

In its report the nominating committee submitted the names of officers and committees as shown on page ix of these Proceedings. The Secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

TREASURER'S REPORT FOR 1933

Receipts

Dues (1933)	$1,692.00		
Reports sold (bound vols. $50.50)	796.08		
Extra pages purchased by authors	280.00		
Reprints sold	502.78		
Etchings sold	222.60		
		$3,493.46	
Interest on money in savings acct.		19.50	
Balance on hand Dec. 20, 1932		1,352.02	
			$4,864.98

Expenditures

Jan. 19	Postmaster, stamps	$ 15.00	
Feb. 27	Mimeographing, etc.	10.00	
Mar. 2	Secretary's office	250.00	
Mar. 10	V. R. Boswell, postage	1.85	
Apr. 28	Postmaster, postcards and stamps	10.00	
May 15	Postmaster, stamped envelopes	33.76	
May 20	L. R. Tucker, refund on dues	3.00	
May 22	W. F. Humphrey, engravings	183.43	
June 28	Postmaster, stamps and postcards	15.00	
July 17	W. F. Humphrey, printing reprints	354.82	
Oct. 2	W. F. Humphrey, printing Proceedings	2,054.33	
Oct. 2	W. F. Humphrey, ptg. programs, 1932 meeting.	38.50	
Oct. 2	W. F. Humphrey, printing letterheads, billheads, labels, etc.	37.64	
Oct. 2	W. F. Humphrey, binding 55 Proceedings	44.00	
Oct. 2	W. F. Humphrey, mailing Proceedings	70.05	
Oct. 25	Postmaster, envelopes	30.90	
Dec. 12	A. S. Colby, mimeographing, stamps	4.65	
Dec. 20	Tax and exchange on checks during year	1.27	
	Total expenditures	$3,158.20	
	Balance on hand, December 20, 1933	1,706.78	
			$4,864.98

Respectfully submitted,
H. B. Tukey, *Treasurer*

Audited and found correct,

J. K. Shaw
G. F. Potter
Committee

A Two-Year Study of Labor and Equipment Used in Spraying Forty-two New Hampshire Orchards

By E. J. Rasmussen, *University of New Hampshire, Durham, N. H.*

PREVIOUS study of the cost of apple production on 12 New Hampshire farms showed that spraying occupies a crucial place in fruit farm management. Frequently, or even generally, the number of men hired for the season is determined by the size of crew necessary to spray the orchard within the very definite time limits available for efficient pest control. Men sufficiently skilled in spraying generally are not available at these very definite intervals unless given employment at other times. Hence any improvement in spraying methods effects a saving not only at the time but throughout the season.

In 1932, the present study was started in 50 orchards in order to obtain further information on this important operation. This is a progress report for 2 years in 42 of the orchards, and covers only man labor and equipment. Costs of materials, yields, investment and other factors also are under study and their relation to the total cost of spraying per bushel of fruit and per tree will be reported later.

Small machines, rated capacity of 5 to 7 gallons per minute, were owned by 57 per cent of the growers. Twenty-four per cent were equipped with medium sized machines, rated capacity 7 to 12 gallons per minute, and 19 per cent owned large machines, rated capacity 16 to 30 gallons per minute. The water supply equipment varied from a bucket and a brook in the orchard, to a portable tank and pump, mounted on a truck. Twenty-one of the growers have refiller attachments on the spray machines, 13 have specially constructed tanks or pipelines for gravity filling, two have both fillers and overhead tanks, five fill from their home water supply through a small hose, one owns a portable tank, and two fill with buckets.

In 1933, the variations in gallons of spray applied per man hour (total gallons of spray applied divided by total man hours) was from 27 to 79 on the small machines, 52 to 158 on the medium sized machines, and 58 to 128 on the large machines with averages of 49, 86, and 93, respectively. Gallons of spray per machine hour (total gallons of spray applied divided by number of hours the machine was operated) varied from 53 to 131 for the small, 117 to 189 for the medium, and 117 to 275 for the large machines, with averages of 86, 153, and 221 respectively. In 1932, the variations in both men and machine hours were similar.

The primary factors which determine the gallons of spray applied per man hour and per machine hour are: (a) Size of crew, (b) topography, (c) water supply, (d) capacity of machine and nozzle, and (e) size of trees.

The size of the crew appears to have the most influence on the number of gallons of spray applied per man hour. One-man crews

with medium or small sized machines are able to apply more gallons of spray per man hour than two-man crews, and two-man crews more than three-man crews. One grower with a medium sized machine in 1933 reduced his spraying crew from two men to one man, and increased the gallons of spray per man hour from 99 to 158. Another grower with a small machine reduced his crew from three men to two men and increased the gallons per man hour from 34 to 47. Reducing the size of the crew on the small and medium sized machines tends to decrease the gallons of spray applied per machine hour. Growers with small machines using two-man crews operate their pumps 25 per cent more efficiently than do those using one-man crews. The grower with the medium sized machine who increased the gallons of spray per man hour 59 gallons by reducing his crew from two to one man, decreased the gallons of spray per machine hour from 199 to 158. Improving some of the other factors may help to offset some of the loss in gallons of spray per machine hour. One grower, for instance, improved his water supply, used a larger capacity nozzle, reduced his crew from two men to one man, and increased the efficiency of his machine 14 per cent and the man labor 122 per cent.

The large machines using two-man crews applied an average of 126 gallons per man hour and 252 gallons of spray per machine hour. With three-man crews, the record was 216 gallons per machine hour and 78 gallons per man hour. In this case, the apparent inefficiency of the larger crews is related to topography and method of spraying. The larger number of gallons applied per machine hour by the two-man crews is due to continuous operation of a large capacity nozzle, made possible by the level orchard site and the practice of spraying closely set uniform trees one side at a time while riding past on the tank. With three-man crews, spraying from the ground, it is the usual practice to spray all around a tree in one operation. Since the nozzles must be shut off while the man is traveling from one side of the tree to the other, or to another tree, such a practice results in intermittent spraying and decreases the efficiency of both man and machine.

The size of the crew to employ depends on the time available to cover the orchard. This will vary with certain sprays. Early in the season, when the delay of a few hours may mean the difference between success and failure in control of scab, a grower may find it necessary to operate the maximum crew in order to obtain the greatest efficiency out of his machine. With the latter sprays, applied primarily for the control of insects, the efficiency of the machine is less important, and during this period smaller crews may be employed economically.

The topography of the orchard site has considerable influence on the spraying operations. It determines the method of spraying, whether from the rig, or the ground, the number of men in the crew, the way the machine is to be drawn, and the size of the machine and nozzle. One orchardist operating a medium sized pump with a two-man crew on a rough site applied 65 gallons of spray per man hour

while another grower using a one-man crew on a level site applied 158 gallons per man hour. Similar examples could be cited for the large and small machines.

The water supply affects the efficiency of both the labor and the machines. Expensive equipment seems not to be necessary. Growers with good refiller attachments and a convenient brook or pond in the orchard are able to apply as many gallons per man and machine hour as those who are equipped with stationary overhead water tanks. Any arrangement which permits quick filling is all that is required. Since only one of the growers reporting owned a portable supply tank, no conclusion could be drawn regarding it.

The size of the machine and nozzle is the fourth factor. Because of the rough topography and small size of the orchards, the medium sized machine appears to be the most efficient under New Hampshire conditions. It delivers a sufficient quantity of spray to supply a nozzle of 6 to 7 gallons per minute capacity, which is as large as the average man can handle from the ground, and is large enough to cover several hundred bearing trees in 3 to 4 days. Considering man labor only, the grower with the small machine employs 75 per cent more labor than the man with the medium or large machines when applying the same amount of spray. Large machines gave only slightly better labor efficiency than the medium sized ones. Other things being equal, we find that the medium sized machine will cover about 78 per cent more trees than the small machine and the large machine about 44 per cent more than the medium sized machine in the same length of time. The proper size of machine to own depends on the size and topography of the individual orchard. At present, few if any of these orchardists need large machines.

Obviously, both man and machine efficiency is greatest when spraying large trees which permit continuous operation of the nozzles. Growers with young trees planted at a distance such that the nozzle must be shut off while traveling from one tree to another, apply less spray per man and per machine hour.

Recent Experiments in Spray Residue Removal from Apples

By F. L. OVERLEY, E. L. OVERHOLSER, and J. L. ST. JOHN,
State College of Washington, Pullman, Wash.

THE placing of a lead tolerance of .02 grains per pound of fruit on the 1933 crop of apples resulted in the use of many kinds of spray programs for codling moth control. In fact, certain growers were given to understand that lead arsenate sprays would not be permitted for the second codling moth brood because of the assumed problem of residue removal. The results of much previous investigational work were thereby thrown aside.

In the Wenatchee district of Washington, alone, over 20,000 chemical analyses for lead and arsenic on official samples were made. Approximately 2 per cent of the official samples analyzed for lead were over the .020 grains of lead per pound of fruit, and 2 per cent of those analyzed for arsenic were over the .01 grains of arsenic per pound of fruit. This represented 186,575 boxes of packed apples and pears, and required the rewashing and repacking of about 250 cars of fruit.

Many experiments have been made with hydrochloric acid in combination with Vatsol, or with salt, or with mineral oil, and with sodium silicate and soap, in different types of equipment, different concentrations, and at different temperatures.

RESULTS USING DIFFERENT MATERIALS

Lead load:—It is often assumed that fruit with the heaviest load of lead and arsenic at harvest time should be the most difficult to clean. This would probably be true if the same spray programs were applied to apples of the same varieties and the growing conditions were the same. On the other hand, experiments have shown that with one spray program certain lots of fruit with a light load of lead or arsenic are often more difficult to clean than fruit receiving another spray program and having a residue load several times greater. For example, one lot of Delicious sprayed with a calyx and six covers of lead arsenate, 3 pounds to 100 gallons at each spray, had an average lead residue at harvest of .169 grains per pound of fruit. A second lot of Delicious from the same orchard sprayed with the same brand of lead but receiving a calyx and first cover of 3 pounds of lead arsenate and .8 gallon of light medium mineral oil, and a third cover of 3 pounds of lead arsenate alone, followed by three oil sprays in combination with other non-lead and non-arsenic materials, showed at harvest time a lead residue of only .051 grains per pound of fruit. With the same washing solution and equipment the lead on the first lot was reduced to .005, but on the second lot to only .015 grains per pound of fruit. The second lot received one of the spray programs officially recommended by certain agencies last May for the purpose of putting less lead residue on the fruit than when lead ar-

senate was used throughout so that residue removal would be easier at harvest.

Manganese arsenate:—When manganese arsenate, 3 pounds to 100 gallons, was used throughout the season in six cover sprays in combination with dog fish oil, linseed oil, or mineral oil emulsified with casein ammonia, the arsenic residue was more difficult to remove from Delicious apples with either HCl or sodium silicate washes than when fruit was sprayed with manganese arsenate and a neutral colloidal spreader or with lead arsenate alone. In general, with fruit sprayed with lead arsenate for the first brood followed by two or three manganese arsenate and oil sprays for the second brood, there has been some difficulty in reducing the arsenic to the tolerance, but the lead has been readily reduced to the tolerance. Experiments indicated that when manganese arsenate sprays were used hydrochloric acid was more satisfactory as a washing solution for arsenic removal before the wax formed on the fruit to any appreciable extent, but the lead was more satisfactorily removed under comparable conditions with sodium silicate. For example, with one lot of fruit so sprayed when washed with HCl at 1.5 per cent, 110 degrees F, in a roller conveyor flood washing machine with 40 seconds immersion in the washing solution, the lead was reduced to .008 and .009 and the arsenic to .006 and .005. When washed with 85 pounds of sodium silicate in a flood underbrush washing machine at 109 degrees F the lead was reduced to .003 and .003 and the arsenic to .012 and 0.18 on duplicate samples. Later in the season, however, after wax developed on the fruit, it was necessary with fruit similarly sprayed to use a tandem wash of HCl and of sodium silicate to successfully reduce both the lead and the arsenic.

Calcium arsenate:—The experimental results indicate that when calcium arsenate combined with oils and spreaders was used throughout the season, HCl was more satisfactory as a wash than was sodium silicate especially with fruit free from much wax development.

Zinc arsenate: — Limited work with early harvested Delicious apples sprayed with zinc arsenate and herring oil shows that the arsenic residue was removed effectively with either HCl or sodium silicate.

Fluorine compounds:—The use of HCl as a washing solution for fluorine sprayed apples is likely to result in injury to fruit so washed (1). When sodium silicate, however, is used to remove fluorine sprays from apples there is much less likelihood of injury from washing. When tandem washes are employed to clean fruit sprayed with fluorine compounds, it seems advisable, in order to minimize the danger of injury, to use sodium silicate before the HCl.

Nicotine oil combinations:—Nicotine sulphate and mineral oil combinations for second brood sprays following heavy applications of lead arsenate for first brood sprays complicated the residue removal at harvest time. Apparently fruit sprayed for the second brood of codling moth with a fish oil-nicotine combination following sprays of lead arsenate for the first brood is more readily cleaned

with respect to both lead and arsenic than is fruit sprayed with a mineral oil-nicotine following lead arsenate sprays. This is especially true when sodium silicate is used as the washing solution. Limited experiments indicate that fish oil-nicotine may be a promising combination spray for use in the control of the second brood of codling moth, which results in no apparent serious problem in residue removal.

Soap type of spreaders:—Experiments show that lead and arsenic residues were more readily removed when combination sprays of lead arsenate with Grandpa's pine tar soap, or with adherene spreader, or Dolmanite spreader, or some of the colloidal spreaders, or when fish oils were used than when lead arsenate alone or in combination with mineral oil was used, or when lead arsenate sprayed fruit was followed with some of the mineral oil non-lead and non-arsenic combinations. With early harvested Jonathan and Delicious, both HCl and sodium silicate were satisfactory as washing solutions when used at the proper temperature and in proper equipment. With the later varieties and as the season advanced, however, sodium silicate was more efficient than was HCl as a washing solution, especially with fruit sprayed with lead arsenate in combination with some of the soap spreaders.

Sodium silicate as a washing solution:—Sodium silicate and HCl were the two major washing solutions used in the fruit districts of the State of Washington during 1933. Some soda ash, "kero wash" and other solutions, however, were used. Each of the solutions had its limitations as to temperatures, concentrations, time, fruit was allowed to remain in the solution, and the fortifying agents used, such as soap, salt, kerosene, Vatsol, and other materials.

Failures with the use of sodium silicate as a washing solution were due in most cases to the use of equipment that had been developed for an acid solution and not for sodium silicate where soap and foam were necessary as a wetting agent. Sodium silicate was more efficient as a wash at higher temperatures and lower concentrations than at higher concentrations and lower temperatures. Often temperatures too high were used. This was especially true with the early harvested fruit when an attempt was made to use sodium silicate in equipment without sufficient soap and proper foam. With fruit where injury was a problem the temperature of the solution could be increased only when the length of time in the solution was decreased. With early harvested fruit before wax had developed, temperatures of 100 to 110 degrees F, with immersion periods of 20 to 40 seconds in the solution, were generally the maximum that could be recommended. Later in the season, however, after wax had developed, temperatures of 110 to even 125 degrees F were satisfactorily used. The temperature and length of time the fruit could safely remain in the solution depended upon the variety, the degree of wax development, the sprays applied and the growing environment of the fruit.

Other Considerations

Foaming:—With sodium silicate it is necessary for an adequate foam to be developed. Soap is an excellent means of developing foam and of effectively wetting the surface of the fruit. With fruit sprayed with fish oil or with some of the soap spreaders, additional soap may not be necessary. It is desirable to have the fruit pass into foam as it enters the washing tank. Kerosene is satisfactory to use in controlling excessive foaming. It is preferable to add, however, only sufficient amount of soap to produce a good foam.

Comparative value of HCl and sodium silicate:—HCl is more satisfactory with fruit sprayed with manganese arsenate, calcium arsenate, lead arsenate combined with lime, or with early harvested and early washed fruit sprayed with lead arsenate alone. With fruit sprayed with lead arsenate and mineral oil, and early harvested and early washed, sodium silicate, when used in a properly equipped washing machine, is equally as effective as HCl. With fruit sprayed with fish oil-lead arsenate, and with fruit sprayed with lead arsenate alone, lead arsenate and mineral oil, harvested late and washed after wax has developed, sodium silicate is superior to HCl.

Delay in washing:—When sodium silicate is used there is no increase in the difficulty of removal of the lead and arsenic residues, but the effectiveness of the cleaning is actually increased by the delay when accompanied by wax development. Furthermore, late in the season, after wax has developed, the fruit will withstand a much more severe washing program without injury, than is the case early in the season.

Equipment suitable for sodium silicate:—When sodium silicate is used with early harvested fruit washed before there is an appreciable development of wax it is imperative that proper washing equipment be employed if satisfactory cleaning is to be obtained. Proper washing equipment for sodium silicate means a machine so constructed, first, that it will handle adequate foam as developed by the addition of soap; second, that it will give an abrasive action with underneath brushes; third, that it is provided with a heavy forceful overhead flood system of agitation, and, fourth, that it has excellent rinsing facilities.

The rigid bar conveyor in either the washing or the rinse tank, especially with sodium silicate, generally is not meeting requirements, because the fruit does not revolve or roll about on its axes and, therefore, the calyx and cavity are not adequately rinsed or drained. The roller type or step-over type of conveyors are preferable in this connection to the rigid bar conveyor.

Continued use of same sodium silicate solution:—In some instances sodium silicate has been satisfactorily used in the washing machine over a comparatively long period of time as a cleaning solution. In other cases calyx end injury developed but was largely overcome by a change of solution or providing a better rinse. Hence, it appears advisable to occasionally allow the solution to settle in the tank and to siphon off the liquid without disturbing the sediment in the bottom of the tank. This sediment is then flushed out of the tank

and discarded. The tank is refilled, using the old solution that was siphoned off and the necessary amount of new sodium silicate and fresh water is added to give the concentration desired.

There may also be some question, however, as to how long the sodium silicate solution can be used without building up a concentration of soluble arsenic to a point where it is difficult to remove it from the fruit by rinsing and thus causing soluble arsenic injury to the fruit. Sodium silicate washing solutions, free of the sediment, from a prewash tank containing 73 pounds of sodium silicate per 100 gallons of washing solution, and also from the main washing tank containing 60 pounds per 100 gallons were analyzed for arsenic and lead after 60,000 boxes of apples had been washed by the same solutions, the concentrations having been kept up by the necessary additions of sodium silicate from time to time. The arsenic that had accumulated in these solutions was in the soluble form. In the prewash tank there were about 560 milligrams of arsenic trioxide and 950 milligrams of lead per liter of the sodium silicate solution. In the main washing tank there were about 360 milligrams of arsenic trioxide and 340 milligrams of lead per liter. These data emphasize the importance of a thorough rinse with clean water, and suggest the desirability of a more frequent change of solution.

Rinsing:—With the use of any of the commonly employed alkalies unless an excellent rinse was provided, the washing solution often resulted in a staining or discoloration about the calyx. The use of long bristle brushes overhead in the rinse section aided in the removal of alkali and in avoiding the staining. Fruit washed with HCl did not show this staining but was more likely to show actual injury unless the rinsing was thorough.

Tandem washes:—Tandem washes were increasingly used this fall, often as a result of necessity. Their use was generally successful. When tandem washes were employed to clean fruit sprayed with lead arsenate excellent cleaning resulted with either the sequence of, first, HCl and second, sodium silicate, or the reverse. With waxy fruit or oil sprayed fruit, possibly sodium silicate may be most effective first so that the wax or oil will not so seriously affect the HCl. From the point of view of appearance and condition of the fruit after washing, however, it appeared generally advisable wherever feasible to use the tandem sequence of HCl first and sodium silicate last.

Fruit injury:—This season there was considerable arsenic injury to the calyx end and also some lenticel injury of apples both before and after washing. This has probably resulted, first, in certain instances because of the original high arsenic load on the fruit with the use of such materials as manganese arsenate and white arsenic; and, second, because of rather frequent rains in north central Washington that occurred before the fruit was harvested or before the fruit was moved from the orchard into the packing sheds or houses. Either factor or both would favor the accumulation of soluble arsenic on unwashed fruit to the degree that it would become toxic and injury would result. These frequent rains where there were delays of 3 or 4 weeks in bringing fruit from the orchards often resulted in calyx

injury even with unsprayed fruit. The water in the calyx excluded from the immediate flesh areas involved the oxygen and lessened the escape of the evolved carbon dioxide, and resulted in disturbances that injured the tissues. The injured areas subsequently were attacked by saprophytic fungi always present in orchards, and secondary rot followed.

Early in the season before any appreciable amount of wax had developed, the fruit was more subject to heat cracks in the skin than was the case after the wax had developed. When McIntosh apples were washed, early in the season shortly after harvest, with sodium silicate at 100 degrees F considerable skin cracking resulted. When a portion of the same lot of McIntosh was washed with sodium silicate at 120 degrees F after 6 weeks storage there was less skin cracking. This was also true with Winesap apples washed early in the season as compared with comparable lots washed after wax had developed on the skin.

Rot control:—Preliminary experiments indicate that fruit washed with sodium silicate does not show so much subsequent rot development as compared with similar fruit washed in HCl.

Literature Cited

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Preliminary Report on the Removal of Spray Residues from New York Apples

By W. T. Pentzer, *Cornell University, Ithaca, N. Y.*

As a result of the enforcement of a lead tolerance on apples of .02 grains per pound for the 1933 season, many apple washers were installed and used in the New York apple districts this past fall. The problem of removal was the most serious in the western New York counties, owing to the spray program required to control the codling moth, and most of the washing equipment was installed in this section.

Investigations on residue removal were begun this past season by the Department of Pomology at Cornell University. The work has dealt with the removal of lead and arsenic; (a) at time of harvest, (b) after being held in cold storage, (c) and after being stored in common storage. The report presented here is a summary of the data obtained to date from about 175 arsenic and lead analyses, and deals primarily with removal at the time of harvest. The writer is indebted to Mr. G. A. Pearce of the Geneva Experiment Station for the lead and arsenic analyses. A complete report of the investigations will be published as a station bulletin.

Nine different lots of heavily sprayed McIntosh, Rhode Island Greening, Baldwin, and King apples from western New York were cleaned in the various types of equipment available in that section. Most of this fruit had received 4 or 5 lead arsenate cover sprays of 2½ to 3 pounds of lead arsenate to 100 gallons of spray solution. The last spray was usually applied between August 1 and 15. This fruit carried, before cleaning, from 1½ to 3½ times the lead tolerance, and about the same relative amounts of arsenic trioxide.

The washing equipment used included the current season's models of Bean, Cutler, and Ideal washers, an old model Bean, and a flotation washer designed by the Department of Agricultural Engineering at Cornell University. The washing equipment, operating with 1 per cent HCl by weight, at temperatures of 50 to 70 degrees F, removed these materials below the tolerances in all cases, with the exception of one lot of McIntosh carrying three times the tolerance and washed in an old model Bean washer.

The brushing and wiping equipment used with western New York equipment included the Trescott and Bean brushers and the Andy Moe wiper. None of the lots of fruit were cleaned below the tolerances with this equipment.

Fruit from the college orchard at Ithaca, which had received late lead arsenate sprays, was washed in ½, 1 and 1½ per cent HCl in a Model E Bean washer and in a Cornell flotation washer. This fruit had received three cover sprays, the last one being applied September 5, with the exception of Greening and Baldwin which received an additional spray October 17 for residue removal experiments. Lead arsenate of 2½ to 3 pounds per 100 gallons was used. This fruit carried from slightly over twice to seven times the tolerances before washing.

With fruit carrying considerable residue, (3 to 7 times the tolerance) the Bean brush washer removed slightly more residue than the flotation washer, even though the exposures to the acid solutions were ½ minute and 2½ minutes, respectively.

Increasing the acid concentration from ½ to 1½ per cent gave increased removal with fruit carrying considerable residue. Acid concentrations of 1½ per cent were necessary to clean some lots of heavily sprayed fruit. No injury from this concentration has been noticed on the Wealthy, Twenty Ounce, McIntosh, Baldwin, Winter Banana, Golden Delicious, Northern Spy, and Greening apples used in these tests.

Some preliminary tests have been made on the removal of residue from fruit which had become waxy or had been sprayed with mineral oil-lead arsenate combinations. Baldwin apples sprayed with only one and two oil-lead sprays early in the season and carrying only 1½ the lead tolerance were cleaned in cold acid solution of 1½ per cent, even though the removal was further complicated by waxiness of the fruit.

McIntosh apples sprayed with four lead arsenate-mineral oil sprays, the last application made as late as August 15, with the fruit carrying over four times the lead tolerance when harvested, have not been cleaned in the Bean washer with 1½ per cent HCl, 49 to 52 degrees F, even with the addition of wetting agents. The wetting agents used were ½ per cent Vatsol, 1 and 2 per cent Grasselli No. 8 and ½ and 1 per cent Grasselli No 4. Turkey Red oil was used as an anti-foam agent in the case of Vatsol. No benefit was obtained with the use of these wetting agents under the above conditions with waxy Wealthy and waxy Twenty Ounce. However, in the flotation washer ½ and 1 per cent Grasselli wetting agent No. 2 gave increased removal of residue from the McIntosh receiving four oil-lead spray applications and from the waxy Twenty Ounce. More extensive tests are being made with wetting agents at different acid temperatures on fruit which is difficult to clean. These will be published later, together with the removal tests with fruit from cold and common storage.

The Relation of Weather to Pollination of the McIntosh Apple

By R. L. Boyd, and L. P. Latimer, *University of New Hampshire, Durham, N. H.*

THE relation of weather to fruitfulness in the plum has been very thoroughly investigated by Dorsey (3). He found that the opening of anthers is prevented or delayed during rainy periods while those already opened may close again. He found further that stigmas retained through a 14-hour period of heavy rainfall enough pollen to insure fertilization. Little else has been reported with relation to the effect of rain on fruit setting after pollen has been placed on the stigma. Previously it had been thought by some that pollen could easily be removed from the pistils by rain or that rain could dilute the stigmatic solution sufficiently to prevent pollen germination.

The effects of temperature have been studied more widely. From the observations of several workers the general conclusion can be drawn that low temperature following pollination may reduce the set of fruit either by injury to pollen or pistils or by slowing down tube growth so that the sperm nuclei do not reach the ovule before embryo sac disintegration commences.

Sometimes, it seems, confusion has arisen from inability to distinguish between the effects of lack of sunshine, rain, and temperature on fruit-setting as a result of pollination under orchard conditions. Experiments under orchard conditions are few. MacDaniels and Heinicke (4) reported that hand pollination gave a greatly reduced set of fruit when the air temperature was low as compared with the set where warm weather prevailed during the blossoming period. That low temperature delays pollen tube growth has been shown by certain workers. This fact alone is often used to account for lack of fruit set when the temperature is low at pollination time.

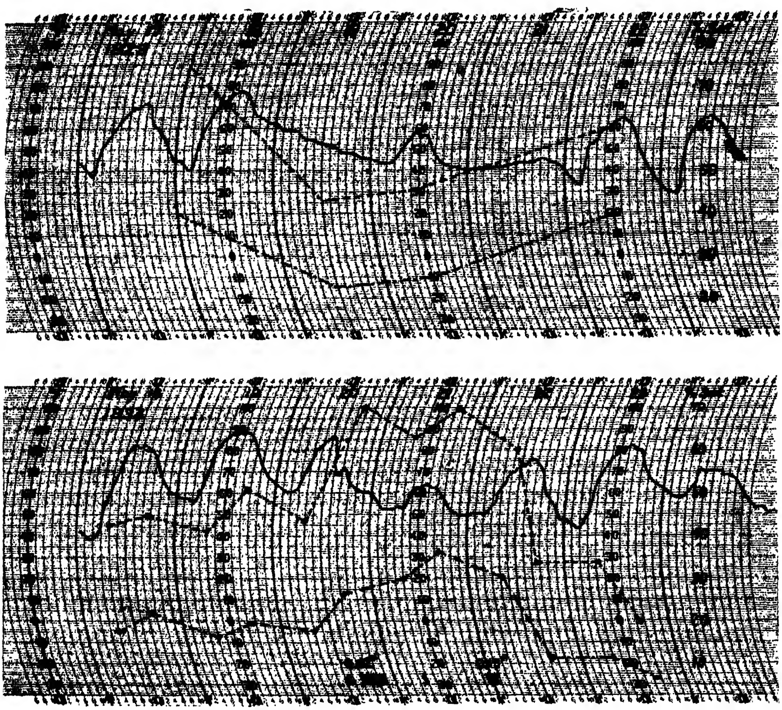
The effect of the time of day when pollen is applied to the stigma on the resultant set of fruit has been barely investigated under orchard conditions.

Observations in 1929

The occurrence in New Hampshire of spells of cold cloudy weather during the blossoming period of the McIntosh apple may occasionally result in a reduced set of fruit. Fig. 1 shows how this is possible. Hand pollinations were made on May 17, 18, 19, 20, and 22, with pollen of Cortland, Delicious, Baldwin, Oldenburg, and Wagener. Inclement weather prevented work on May 21. A total of 4695 flowers were pollinated (1553 spurs). Counts of fruit set were made after the June drop. The results were similar for the different crosses and the average set of fruit for all crosses is indicated in Fig. 1.

Forty per cent of the flowers pollinated during a mild sunny period (May 17, 18) set fruit. May 19 was a cloudy and showery day with

the temperature between 50 and 54 degrees F during the hand pollination period. The set of fruit resulting was 22.5 per cent. On May 20, the temperature ranged between 47 and 56 degrees F while hand pollinations were being made. The day was partly cloudy, with rain in the afternoon. In this case, 25 per cent of the flowers set fruit.



----- PERCENT SPURS SETTING FRUIT. TEMPERATURE.
–·–·– " FLOWERS " " . RAINFALL.

FIG. 1. Set of fruit resulting from hand pollination of the McIntosh Apple. The curves for percentage set of flowers and per cent of spurs setting fruit are plotted through points representing the amount of set resulting from the application of pollen at 8 a. m. and 5 p. m. on different days.

On May 21 the temperature did not rise above 45 F, and light rain fell all day. May 22 was fair and mild. The set of fruit was 39.5 per cent from flowers pollinated on this day. It is not easy to determine whether the poor set on May 19 and 20 was due to rain, lack of sunshine, low temperature at the time of pollination, or to the abnormally low temperature that followed. The last explanation seems the most plausible, in that pollen germination and tube growth may have been slowed down by the low temperature of May 20 and 21, preventing many pollen tubes from reaching the ovaries in time. Warm, fine weather followed for several days after May 23.

Observations in 1933

In 1933 it was decided to test further the effect of dry sunny weather or of cloudy or rainy weather at blossom time on fruit setting. The writers believed that there might also be some difference in the amount of fruit setting between flowers pollinated in the early morning and those pollinated in the afternoon. Auchter (1) noted on one day that 15 per cent of the blossoms of Winesap pollinated at 6:30 a. m. with Grimes set fruit, while only 5.55 per cent and 4.5 per cent set occurred on blossoms pollinated at 12 p. m. and 7:30 p. m. respectively. In another year, the same results were obtained with noon as with night pollination.

A moderately vigorous McIntosh tree, 14 years old, was caged with cheesecloth just before blossoming. As soon as the blossoms began to open, cross pollination was begun. Wealthy pollen was used exclusively. On May 18 and on the 5 days following, unemasculated blossoms were pollinated at 8 a. m. and at 5 p. m. The terminal blossom and enough lateral ones were removed from each spur at the time of pollination to leave only three blossoms per cluster. Blossoms chosen were those nearest one another in stage of development and open enough for the pistils to be receptive.

Approximately 125 spurs or 375 blossoms were used at each pollination. Usually two or three branch units were used each time and an attempt was made to have them as far apart as possible on the tree in each test and also to have the distribution representative of lower and of upper parts of the tree. As in 1929, counts were made after the June drop.

Fig. 1 shows the results obtained, together with the climatic conditions existing during the pollination period. May 18 and 19 were clear with bright sunshine. A thunderstorm occurred shortly after noon on May 20 and was followed by another at 4 p. m. with heavy rain. Good conditions were therefore afforded for studying the washing effect of rain on the stigmas. The following day, May 21, was moderately cool and cloudy, the sky not clearing until after the shower at midnight of that day. Bright sunny weather prevailed again on May 22 and 23. Without exception, a better set of fruit occurred with flowers pollinated at 5 p. m. than with those pollinated at 8 a. m. of the same day.

A larger set of fruit was obtained when hand pollination was performed during humid, cloudy, or rainy weather with mild temperature. This is indicative of the beneficial effects of such conditions over dry and warm sunny weather. The temperature conditions, except on May 21, were undoubtedly very favorable for good pollen tube growth. It is possible, however, that conditions favorable for pollen tube growth after penetrating into the style might not have been always so favorable for pollen germination or for the initial stages of tube growth. There is some evidence that high humidity favors pollen germination and tube growth outside of the stigma (5, 7). It is possible, therefore, that the better results obtained from pollination performed on cloudy days were due to high humidity.

On bright sunny days with cool nights, the stigmatic secretion may become dried during the heat of the day (6). This would be injurious to pollen grains that had commenced to germinate but had not yet penetrated into the stylar tissue. Of course, pollen grains that do not start tube growth immediately would be able to germinate when moisture conditions became more favorable in the evening. Therefore the possibility exists that a small percentage of the pollen grains applied to the flowers in the morning were under conditions favorable enough for germination to commence but not favorable enough to promote further growth of the tube when the stigmatic surface became dried during the morning. Such conditions must be severe for the unprotected pollen tube and its specialized nuclear contents. Fewer of the pollen grains placed on the stigmas at 5 p. m. would probably commence germination immediately than at 8 a. m. because of the lower humidity at the time. Evening dews would subsequently make the environment more favorable. Even at that, there would probably be a considerable number of grains wasted because of germination followed by unfavorable conditions. The average increase of 75 per cent in fruit setting when pollination was done during the more humid period may be largely the result of exceptionally favorable conditions for the retention of stigmatic secretions and for pollen tubes that might possibly start growing through the air to reach the stigmatic tissues.

The rapid falling off in set after May 22 can be explained by the fact that some of the stigmas had turned brown and many flowers had passed the receptive condition. By May 24 practically all blossoms were useless for pollination purposes.

Strong evidence was obtained that heavy rain does not wash pollen from the stigmas in a quantity detrimental to obtaining a satisfactory set of fruit. In fact, it seems that as good a set is obtained under favorable temperature conditions when pollination is followed by heavy rain as when it is followed by cloudy weather and high humidity without rainfall. For example, Fig. 1 shows that the 5 p. m. pollination on May 20 was made between two showers. Many of the stigmas were covered with water at the moment of pollination and five hours of rainfall followed which was heavy between 5 and 6 p. m. The heaviest set of fruit resulted from flowers pollinated at this time. It seems to be clear from the results that the possible great dilution of stigmatic fluid did not interfere appreciably with good germination and initial tube growth of the pollen.

In conclusion, it is the belief of the writers that contrary to the results of Bradbury and Roberts (2) with cherries, lack of sunshine and cloudy weather is not detrimental to fruit setting in the apple. It is the belief rather that bright sunshine and low humidity at the time of and immediately following pollination is more detrimental than beneficial. Failure in times of cloudy weather to obtain a set of fruit in the apple, in the experience of the writers, occurred only when such weather was accompanied by an extended period of low temperature, since higher temperatures under cloudy skies gave exactly opposite results. It should be emphasized that these con-

clusions relate only to the effect of weather on fruit setting itself and not to its effect on bee activity.

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Apple Pollination Studies in Maryland

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York Imperial

THE results of self and cross-pollination experiments with the York Imperial apple indicate that the variety should be classified as commercially self-unfruitful. Powell (8) selfed 134 flowers and obtained a set of 6.7 per cent on May 14 (before the June drop); only one of the fruits matured and it was small and seedless. Lewis and Vincent (5), Alderman (1), and Knowlton (4) all obtained less than 1 per cent set of York Imperial flowers from selfing. Murneek, Yocum, and McCubbin (7) during an "on year" in Missouri obtained 1.1 per cent set of the flowers after the June drop when the flowers had been bagged but not brushed, and 4.4 per cent set where the flowers were bagged and brushed with York Imperial pollen.

In the Shenandoah-Cumberland fruit sections of Maryland, Virginia, West Virginia, and Pennsylvania, the York Imperial variety is commonly set in rather large blocks which would seem to provide poor conditions for cross-pollination. Most of these "solid blocks" have the reputation of yielding heavy crops biennially and have given very little field evidence indicating that the variety has pollination troubles. Close observation of these "solid blocks" usually reveals many trees of other varieties scattered promiscuously throughout the orchard. The Green Lane Orchard at Hancock, Maryland, is a rather good example of a large block of York Imperial trees which usually set well. Nearly 10 per cent of the trees in this orchard, however, are miscellaneous varieties, mostly Grimes Golden, Ben Davis, and Jonathan.

A 200-acre orchard of York Imperial trees at Tonoloway Ridge, near Hancock, Maryland, has afforded a very excellent opportunity to observe and study the pollination requirements of this variety. The orchard is now about 30 years old. Previous to about 1919 it had been in sod culture and had received very little pruning, spraying, or fertilizing. The low yields were attributed to low vigor and poor care. About 1920, the orchard was taken over by the American Fruit Growers, Inc., and a good system of pruning, spraying, and fertilizing introduced in an effort to build up production. By 1923 the orchard was in good vigor, the trees bloomed well, and there appeared to be plenty of bees for pollination purposes. The yield, however, continued to remain below normal for the variety. Lack of cross-pollination was suspected as the cause of the poor set of fruit. Since about 1924, buckets of flowers of various varieties have been suspended in the trees at various intervals throughout the entire orchard during the bloom period. The set of fruit has been markedly increased by this practice. More recently a large number of trees uniformly distributed throughout the orchard have been top-worked to other varieties for cross-pollination purposes. Observations in

this orchard indicated that the variety was commercially self-unfruitful and that its pollination requirements should be studied.

Experimental results with York Imperial:—Experiments with this variety were conducted in the orchard at Tonoloway Ridge, and on trees located at College Park. In Table I are given the results obtained by permitting each pollen variety to compete on each spur as previously described by Wentworth, Furr, and Mecartney (9). In this experiment the central flower of each spur was removed and the five remaining flowers pollinated with the various pollens. The per cent set of the flowers was recorded immediately after the June drop. From 20 to 25 spurs were pollinated on each of three trees. Contamination by bees was prevented by covering the spurs with "Glassine" bags.

TABLE I—POLLINATION RESULTS ON YORK IMPERIAL. POLLEN VARIETIES COMPETING ON SAME SPURS

Pollen	Number Flowers Pollinated	Set May 27	
		Number	Per Cent
Starking	70	31	44.3
Red Rome	70	36	51.4
Red Duchess	70	36	51.4
Summer Rambo	70	2	2.9
York Imperial	70	0	0.0

Table II gives the results obtained from four York Imperial trees where from two to three flowers of each spur were pollinated with the same pollen variety. In this case the per cent set of spurs with one or more fruits immediately after the June drop is recorded.

TABLE II—POLLINATION RESULTS ON YORK IMPERIAL. POLLEN VARIETIES COMPETING ON SEPARATE SPURS

Pollen	Number Spurs Pollinated	Per Cent Spurs with Fruit	
		May 28	July 8
Starking	36	80.6	41.7
Red Rome	39	76.9	30.8
Red Duchess	42	69.0	31.0
Summer Rambo	41	70.7	31.7
Jonathan	51	54.9	39.2
Melba	33	72.7	33.3
Wealthy	40	85.0	37.5
Joyce	42	59.5	28.6
York Imperial*	83	4.8	3.6
York Imperial†	51	2.0	0.0
Open Pollinated	100	18.0	14.0

*Flowers brushed. †Flowers not brushed.

Table III presents the results obtained by using the branch unit method of doing pollination work as described by MacDaniels (6). In this case cheese cloth bags (3 feet by 6 feet) were used to prevent contamination by bees.

TABLE III—POLLINATION RESULTS ON YORK IMPERIAL. POLLEN VARIETIES COMPETING ON DIFFERENT BRANCHES

Pollen	Number Branch Units	Total Number Spurs	Number Spurs Blossoming	Number Spurs with Fruit‡	Per Cent Set of Blossoming Spurs‡
Starking	3	379	293	174	59.4
Red Rome	3	434	312	134	42.9
Red Duchess	3	440	346	161	46.5
Summer Rambo	3	341	279	42	15.1
Jonathan	3	434	332	155	46.7
Melba	3	414	343	114	33.2
Rome Beauty	3	384	315	176	55.9
York Imperial*	1	186	135	8	5.9
York Imperial†	2	318	267	3	1.1

*Brushed. †Not Brushed. ‡Recorded May 28 (after June drop).

The data show several points of interest. In Tables I, II, and III the set obtained from selfing York Imperial flowers indicates that the variety is commercially self-unfruitful. Brushing the flowers of York Imperial pollen increased the set slightly as compared with no brushing. The value of Summer Rambo as a pollenizer for York Imperial is relatively low. In Table I, where Summer Rambo pollen was forced to compete on the same spurs with three effective pollenizers, it appears to be very weak. In Table II, involving cases where there was no other pollen to compete with Summer Rambo, a very good set was obtained. In Table III, however, the average set from three branches pollinated with Summer Rambo is below the requirements for a commercial crop. York Imperial set a commercial crop when pollinated by Joyce, Jonathan, Melba, Red Duchess (Daniels Strain), Red Rome, Rome Beauty, Starking, and Wealthy.

Other investigators have shown that York Imperial may be satisfactorily pollinated by Ben Davis, Delicious, Grimes Golden, Missouri Pippin, Northwestern, and Wagener.

York Imperial as a pollenizer:—Several investigators have used York Imperial as a pollenizer for other varieties. From the data thus obtained it appears that the following varieties will set a commercial crop when pollinated by York Imperial pollen: Arkansas, Blenheim, Delicious, Golden Delicious, Gravenstein, Jonathan, McIntosh, Missouri Pippin, Northern Spy, Northwestern, Rome Beauty, Stark, Stayman, Wagener, and Winesap. The pollen of York Imperial also germinates well on agar agar media.

GOLDEN DELICIOUS

Investigations by Howlett (2), Knowlton (3), Schrader and Whitehouse (unpublished), and others indicate that Golden Delicious is very weak in its ability to set fruit with its own pollen. Results

obtained by Overholser and Overley,[1] however, indicate that the variety was markedly self-fruitful in Washington in 1930. They selfed 189 flowers and obtained a set of 35 per cent after the June drop. In this case selfing was as effective as cross-pollination by Starking, Jonathan, Winter Banana, or Delicious.

Experimental results with Golden Delicious: — The branch unit method as described by MacDaniels (6) was used in all pollination work with this variety. The results, recorded in Table IV, were obtained in 1931, 1932, and 1933 from 18 Golden Delicious trees. The trees were all from 8 to 10 years old and were in good vigor. From two to ten unit branches were pollinated with each pollen variety used. All replications of the same variety of pollen were located on different trees to compensate for tree and branch variability.

TABLE IV—POLLINATION RESULTS ON GOLDEN DELICIOUS. POLLEN VARIETIES COMPETING ON DIFFERENT BRANCHES

Pollen	Number Branch Units	Total Number Spurs	Number Spurs Blossoming	Number Spurs with Fruit§	Per Cent Set of Blossoming Spurs§
Grimes Golden	5	680	403	272	67.5
Starking	7	778	286	188	65.7
Golden Delicious*	7	769	311	5	1.6
Golden Delicious†	1	153	43	0	0.0
Golden Delicious‡	1	165	67	0	0.0
Golden Delicious§	1	130	44	2	4.5
Delicious	6	714	326	186	57.1
Red Duchess	5	601	277	177	63.9
Red Rome	4	512	131	60	45.8
Melba	4	509	221	137	62.0
Northern Spy	2	201	119	65	54.6
Chenango	2	297	103	80	77.7

*Flowers not brushed. †Terminal flowers brushed. ‡Terminals and one lateral flower brushed. §Recorded after June drop.

From Table IV, it is apparent that pollen from Grimes Golden, Starking, Delicious, Red Duchess, Red Rome, Melba, Northern Spy, and Chenango set a commercial crop on Golden Delicious. Melba is a very early blooming variety in Maryland, however, and probably would not be a good pollenizer for Golden Delicious under orchard conditions. Golden Delicious proved very weakly self-fruitful and should be classified as commercially self-unfruitful in Maryland.

Golden Delicious as a pollenizer:—Numerous workers have used Golden Delicious pollen on other varieties with varying degrees of success. A review of the literature and of unpublished Maryland data indicates that satisfactory commercial crops may be expected on the following varieties with Golden Delicious as pollenizer: Baldwin, Ben Davis, Chenango, Delicious, Ensee, Gallia Beauty, Grimes Golden, Jonathan, King David, Lowry, McIntosh, Northern Spy,

[1]Unpublished data presented at the twenty-seventh annual meeting of the Wash. State Hort. Soc.

Red Rome, Red Spy, Richared, Rome Beauty, Stark, Starking, Stayman, Williams, Winesap, and Wilson Red June.

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Experiments in Spraying Apples for the Prevention of Fruit Set

By E. C. Auchter, and John W. Roberts, *U. S. Department of Agriculture, Washington, D. C.*

Introduction

DURING the past winter and early spring apple growers in various parts of the country requested information concerning sprays that when applied at or before blossoming time would entirely prevent fruit setting by completely destroying either the opening fruit buds or the blossoms without injury to the tree, and without the loss of an appreciable number of leaves. They stated that for economic reasons they might wish to prevent for one year fruit set in (a) certain varieties, (b) certain portions of their orchards, (c) certain entire orchards. In such cases they wished to save the expense of caring for a crop by destroying *all* blossoms, so that no fruits would develop on these trees.

Since practically no knowledge on this subject was available, preliminary experiments were conducted last spring in Arkansas, Missouri, Indiana, Georgia, and North Carolina. The sprays were applied and results recorded at Fayetteville, Arkansas, by John C. Dunegan, using trees furnished by the University of Arkansas; at Mountain Grove, Missouri, by M. A. Smith and H. B. Johnson, using trees furnished by the Missouri Fruit Experiment Station; at Vincennes, Indiana, by Leslie Pierce, using trees furnished by W. C. Reed & Sons; at Cornelia, Georgia, by Lee M. Hutchins and C. H. Alden, using trees furnished by the Georgia State Board of Entomology; and at Raleigh, North Carolina, by Ivan D. Jones, using trees furnished by the North Carolina Agricultural Experiment Station.

Plan of Experiments

The varieties of apples used were: In Arkansas, Oliver and Stayman; in Missouri, Beach; in Indiana, Oldenburg; in Georgia, Arkansas Black, Stayman Winesap, Winesap, and Yates; in North Carolina, Yates. All sprays were applied by means of power outfits developing 250 to 400 pounds pressure, with rods at the lower pressures (North Carolina and Arkansas) and with guns at the high pressures (Missouri, Indiana, and Georgia). In some cases only half the tree was sprayed, the other half being held as a check; in all other cases entire trees were sprayed, with adjacent trees of the same age and variety held as checks. Some trees, as shown later, were sprayed in the late cluster-bud stage, others at or near full bloom, and some were sprayed at both these times.

The sprays used were: calcium polysulphide (liquid lime-sulphur), 1 gallon to 8–10; sodium polysulphide, 1 pound to 5 gallons; copper sulphate 4 pounds to 50 gallons; sodium nitrate, 8 pounds to 50

gallons; zinc sulphate 8 pounds to 50 gallons; and oil emulsion (government formula viscosity 250), 2¼ gallons to 50.

Calcium polysulphide, sodium polysulphide, and oil emulsion were tried, not only because it was thought they would prevent fruit set, but also because they are common insecticides easily obtained; the first two are also fungicidal. In addition, they should be effective for some time after they are applied. Copper sulphate, zinc sulphate, and sodium nitrate were chosen because it was thought that, remaining soluble, they would prevent setting by killing quickly; and though they were expected to cause some foliage injury, it seemed likely that continued foliage injury would be avoided because they would soon be washed away by rain. In addition, it seemed likely that the copper sulphate and zinc sulphate might help to prevent scab and blight and that the sodium nitrate might save a fertilizer application and aid the trees in recovering from any spray injury caused by its application.

Results of Experiments

Calcium polysulphide, applied at either late cluster-bud or full-bloom stage, did not prevent or materially reduce the set in any of the experiments, and caused only slight foliage burn. In Georgia, applied at the full-bloom stage, it caused slight spur injury; and in Arkansas, applied at either the late cluster-bud or full-bloom stage, it reduced the size of the leaves and retarded growth somewhat, but apparently caused no serious injury.

Sodium polysulphide was used only in Arkansas and Missouri. In Arkansas, when applied at late cluster-bud stage, it noticeably reduced the set, caused tip burning of the leaves and retarded their growth; in Arkansas and Missouri, when applied at full-bloom, it entirely prevented fruit setting but caused severe foliage injury, destroying, in Arkansas, at least 90 per cent of the leaves. In Arkansas, one half-tree which received both the late cluster-bud and the full-bloom applications showed stunting (sulphur shock) throughout the season.

Copper sulphate, applied at the late cluster-bud stage in Arkansas, killed 75 per cent of the blossom buds and injured the leaves; at full-bloom it almost entirely prevented fruit setting, and caused severe foliage injury but not total defoliation. The fruit which set was severely russeted. In Missouri, at the full-bloom stage, it entirely prevented fruit set, but caused severe foliage injury. The trees recovered quickly, producing new leaves which remained uninjured. Applied at full bloom in Indiana, it reduced the set about 50 per cent, but severely injured all leaves then open. By June 15 the injured leaves had fallen and the foliage of the tree as a whole appeared only slightly inferior to that of adjacent untreated trees. It also caused severe russeting of the fruits which set. In Georgia a 6–50 solution produced the same results as the 4–50 solution. Both solutions applied at the full-bloom stage killed all blossoms, but caused severe leaf, twig, and spur injury. In North Carolina, an application at the late cluster-bud stage, followed by one at the blossom stage, reduced

fruit set about 65 per cent and injured about 30 per cent of the leaves, but there was no defoliation and growth apparently was not stopped.

Sodium nitrate applied at the late cluster-bud stage in Arkansas and followed immediately by dry weather, gave no appreciable results, but when applied at full bloom and followed immediately by wet weather, it completely destroyed the blossoms and leaves. A Stayman tree added to this plot gave the same results as the Oliver variety. In Missouri, applied at full bloom, it entirely destroyed all blossoms, but caused severe foliage injury. The trees recovered quickly, producing new leaves that remained uninjured. In Indiana, when applied at the full-bloom stage, it reduced the set by 50 per cent, and severely injured all leaves then open. Individual leaves were injured less severely than by copper sulphate. By June 15 the injured leaves had fallen and the foliage of the tree as a whole appeared only slightly inferior to that of adjacent untreated trees. In Georgia, when sodium nitrate was applied at nearly full bloom, the set was reduced appreciably and there was considerable leaf burn. In North Carolina the set was reduced about 35 per cent by an application in late cluster-bud stage followed by one at the blossom stage. The margins of about 20 per cent of the leaves were severely injured, but there was no defoliation and growth was not checked. The foliage injury was less severe than with copper sulphate.

Zinc sulphate was used only in North Carolina at the late cluster-bud stage followed by another application at the blossom stage. Fruit set was reduced about 20 per cent and there was slight spotting of about 20 per cent of the leaves.

Oil emulsion was used only in Georgia. Although this spray when applied at late cluster-bud stage did not immediately prevent a set of fruit, most of the young fruits fell in late spring or early summer; when the crop was harvested, on September 9, an unsprayed check tree produced 1,230 fruits, while a sprayed tree produced only 27 fruits, indicating a crop reduction of about 98 per cent. All open blooms were killed by the spray, and spray-drift from this application reaching an adjacent Yates tree that was in nearly full bloom killed all open blossoms, with but slight foliage injury. If applied directly severe foliage injury would be expected.

In the hands of growers in Maryland and Missouri lime-sulphur proved ineffective in the late cluster-bud and full-bloom stages. Oil emulsion in full bloom reduced the crop about 85 and 65 per cent respectively, but injured the leaves and checked growth. Iron sulphate showed some promise.

The discrepancies in the results from the different regions may be partly explained by differences in tree vigor, but the principal factor probably was the weather. In all cases the complete or appreciable reduction of set, the severe foliage injuries, and the single case of severe twig and spur injury resulted from applications immediately preceding a rainy period. Applications followed by dry weather were not as effective in reducing set and caused much less leaf injury and no twig or spur injury.

Conclusion

On the basis of these results, none of the sprays was completely satisfactory. Those that entirely prevented fruit set injured the leaves severely, and it is questionable what the effect will be upon the set of fruit buds and fruit for next year. It would seem that sprays strong enough to kill all blossom buds in the late cluster-bud stage are likely to injure twigs, fruit spurs, and leaves severely, and those strong enough to kill open blossoms are likely to destroy the leaves also. It is possible that some spray such as a dormant strength oil-emulsion, applied when the cluster buds have just opened but before the pedicels have separated or lengthened to any extent, may destroy all clusters actually hit with no appreciable or permanent injury to later foliage, even if the first two or three small leaves which are open at this time are injured. However, since the time of fruit bud opening varies on old spurs, young spurs, lateral buds and terminal buds, it probably would not be possible to destroy 100 per cent of the blossoms on a tree with only one spray application. Further studies will be made next spring.

The Effect of Various Bactericides on the Set of Fruit and the Germination of the Pollen of the Apple

By L. H. MacDaniels, E. M. Hildebrand, and A. B. Burrell, *Cornell University, Ithaca, N. Y.*

THE effect on the set of fruit of spraying apple trees while in bloom with various bactericides has an important bearing on the feasibility of spraying in bloom to check the spread of fire blight. Such investigation is appropriate at this time in connection with the project in the Plant Pathology Department at Cornell in which the spraying of blossoms is being tested for the control of fire blight. The present study was carried out along the lines of earlier studies (1, 2) on the effect on the set of fruit of spraying apple trees at various stages of bloom with sulfur fungicides for the control of apple scab. In these studies it was shown that although sulfur applied to the stigma of a given flower before or at the time of pollination prevented that flower from setting, application approximately 24 hours after pollination did not inhibit the set. It was also evident that under good pollination conditions enough blossoms set to give a crop in spite of any reduction in set caused by spraying in bloom.

Effect on Set of Fruit

In the present study the branch-unit method (3) already described elsewhere was used throughout. The results of one series of experiments conducted in the Champlain Valley are given in Table I. In this series three Northwestern Greening trees, about 14 years old, were selected for equal vigor. On two of them the branches were bagged and when in full bloom pollen applied by hand. Five hours after pollination, the various chemicals were sprayed or dusted on the blossoms. On the third tree the branch units were not bagged. Sprays and dusts were applied while the tree was in full bloom, but no other treatment was given. It is clear that the open pollinated tree had a considerably higher average set than either the treated or the check branches on the tree with the bagged branches. This is in line with the previous experience which has indicated that the set-reducing effect of dust and sprays applied at any one time tends to be offset by the setting of blossoms which were fertilized before the spray material was applied, or which opened after the application. As compared with the checks on the same tree, it will be noted that the various substances except possibly copper sulphate, calcium hydroxide, and Bordeaux mixture caused little reduction in set.

In a series of experiments at Ithaca, New York, four branch-units were bagged on each of six McIntosh trees, about 20 years old. The following substances and concentrations were used: Copper sulphate 1–200 (parts by weight); calcium hydroxide 3–400, Bordeaux mixture 1–3–200 and 1–3–400, and zinc lime 1–1–100 and 1–1–200.

TABLE I—EFFECT OF BACTERICIDES ON SET OF FRUIT IN NORTHWESTERN GREENING APPLE, PERU, N. Y. SPRING, 1933. BLOSSOMS SPRAYED 5 HOURS AFTER HAND POLLINATION.

Material and Concentration (Parts by weight)	No. Spurs	Spurs Blossoming (Per cent)	Blossoming Spurs with Fruit (Per cent)	
			June	July
Tree 1. Branches bagged and hand pollinated				
$CuSO_4$ 1-400	135	87	31	12
$Ca(OH)_2$ 3-400	60	93	25	9
Bordeaux 1-3-400	120	84	29	7
Zinc lime 1-1-200	123	88	42	11
Crystal violet 1-5000	131	89	39	12
$CuCO_3$ .... Dust	162	90	31	14
Cu_2O .... Dust	102	86	39	16
Brilliant green 1-5000	98	89	37	20
Malachite green 1-5000	116	75	46	26
Methyl violet 1-5000	132	86	48	17
Tree 2. Branches bagged and hand pollinated				
$CuSO_4$ 1-400	82	56	26	7
$Ca(OH)_2$ 3-400	103	90	40	10
Bordeaux 1-3-400	104	77	30	4
Zinc lime 1-1-200	101	72	27	11
Crystal violet 1-5000	113	89	35	11
$CuCO_3$ .... Dust	67	78	31	12
Cu_2O .... Dust	65	85	42	15
Brilliant green 1-5000	126	96	44	21
Malachite green 1-5000	99	91	39	12
Methyl violet 1-5000	125	82	36	18
None (hand pol. ck.)	99	87	37	13
Tree 3. Natural open pollination				
$CuSO_4$ 1-400	118	75	61	19
$Ca(OH)_2$ 3-400	103	61	73	27
Bordeaux 1-3-400	100	94	75	29
Zinc lime 1-1-200	96	91	84	10
Crystal violet 1-5000	89	84	77	25
$CuCO_3$ .... Dust	112	88	79	29
Cu_2O .... Dust	96	82	76	9
Brilliant green 1-5000	88	81	94	28
Malachite green 1-5000	97	68	89	36
Methyl violet 1-5000	134	78	82	28
None (naturally pol. ck.)	105	91	82	28

The substances were applied with a sprayer (a) at the time of pollination, (b) 24 hours before pollination, and (c) 24 hours after pollination. In none of the treatments was any consistent or significant decrease in the set of fruit obtained, except possibly copper sulphate 1–200. This substance burned the petals somewhat. A complicating factor in this series of experiments was the presence of fire blight which destroyed many of the spurs, approximately 18 per cent on the check branches. There is some indication that the spraying actually increased the set as compared with the checks because of the partial control of fire blight on sprayed branches. In 4 out of 6 trees, the average set on the treated branches was equal or

greater than that obtained on the check of the same tree. The average set of all 18 treated branches was 24.9 as compared with 22.2 per cent for the six checks. This is suggestive rather than significant.

In the third series of experiments, at Morton, New York, five out of seven selected branch units were bagged on each of three 22-year-old McIntosh trees. The following dyes were used at a concentration of 1–2000: Malachite green, light green, methyl violet, and brilliant green. The dyes were applied at the time of pollination, and after an interval of 24 hours, all treatments were duplicated on different trees. In no case was the difference between the treated hand-pollinated branches and the hand-pollinated checks significant. There is some indication, however, that application of dyes decreased the set on the branches that were not hand-pollinated. The average percentage of blossoming spurs maturing fruit on six branch units sprayed with various dyes was 18.9 per cent, as compared with an average set of 30.2 per cent on 16 branch-units exposed in the same manner but not treated with dyes. This is in line with the results obtained by spraying apple blossoms with fungicides, which indicated that under conditions where lack of cross-pollination was a limiting factor the set was reduced by spraying in bloom.

Effect on Germination of Pollen

Sulphur has been shown in previous reports to inhibit or reduce apple pollen germination, under certain specified conditions (1, 2). In 1929, Niethammer (4) studied the effect of 16 trade preparations used as fungicides or insecticides in Germany, on the germination of pollen of 27 species of plants, mostly ornamentals, but including the apple, pear, cherry, plum, apricot, and orange. In preparing the culture media 1 per cent of the various substances was added to cane sugar solutions of various concentrations. Although there was considerable species variation, the pollen of the apple and the pear was injured by many of the substances tried, particularly lead arsenate, tar oils, carbolineum, and copper compounds. For the most part, nicotine-soap, lime-sulphur, and colloidal sulphur were considered only slightly harmful. In fact, the author considered that stimulation was obtained with some of the sulphur compounds.

In the present investigation, carried out by E. M. Hildebrand, pollen germination tests were tried with the same substances which were used in field experiments with fire blight control. Part of the results are given in Table II.

A serious reduction in the germination of pollen was secured with all substances, except methyl violet at a concentration of 1–100,000. In these experiments the chemicals were mixed with the medium just before it hardened, except that the dusts were blown onto the surface of the agar after the pollen had been placed thereon. To get direct comparison of the effect of different substances blown onto the surface of the media, the atomizer of duster was clamped at a distance of 1 foot from the surface of the petri dish, which was clamped in a vertical position. The number of puffs refers to the number of times the atomizer was discharged against the surface.

TABLE II—EFFECT OF VARIOUS BACTERICIDES ON GERMINATION OF POLLEN. (MEDIUM 10 PER CENT SUGAR, 1½ PER CENT AGAR SHREDS*)
Three Trials Averaged with Each Material

Substance Used	Concentration and Per cent Germination					Length of Tube†
Series 1—Quince Pollen—Check Germination 47 Per cent, 4-8 x Tube Length						
$CuSO_4$	Conc.	1–200	1–400	1–800	1–1600	4X
	Per cent	0	0	.3	30.0	
$Ca(OH)_2$	Conc.	3–50	3–100	3–200	3–400	1–4X
	Per cent	0	.3	1	.3	
Bordeaux mixture	Conc.	1–3–50	1–3–100	1–3–200	1–3–400	1–4X
	Per cent	0	0	0	.6	
Oxo bordeaux	Conc.	4–100	2–100	1–100	1–200	1–4X
	Per cent	1.3	.3	1.6	2.0	
Powdered bordeaux	Conc.	4–100	2–100	1–100	1–200	1–4X
	Per cent	1.3	1.3	1.0	2.3	
Series 2—Apple Pollen—Check Germination 94 Per cent, 9-12 x Tube Length						
$CuSO_4$	Conc.	1–50	1–100	1–200	—	1–3X
	Per cent	0	.3	0	—	
$Ca(OH)_2$	Conc.	3–50	3–100	3–200	—	2–8X
	Per cent	18	17	34	—	
Bordeaux mixture	Conc.	1–3–50	1–3–100	1–3–200	—	1–6X
	Per cent	10.7	16.3	17.0	—	
Zinc-lime	Conc.	4–4–50	4–4–100	4–4–200	—	2–4X
	Per cent	0	0	1.3	—	
Brilliant green	Conc.	1–1000	1–10000	1–100,000	—	2–8X
	Per cent	0	4.3	34.0	—	
Malachite green	Conc.	1–1000	1–10000	1–100,000	—	1-8X
	Per cent	0	.7	29.3	—	
Methyl violet	Conc.	1–1000	1–10000	1–100,000	—	2–10X
	Per cent	27.7	65.0	87.0	—	
Copper lime dust 20-80	Conc.	4 puffs	2 puffs	1 puff	—	3–12X
	Per cent	11.0	19.7	19.0	—	
Copper resinate dust	Conc.	4 puffs	2 puffs	1 puff	—	2–10X
	Per cent	4.0	27.3	68.3	—	

*The various spray materials were mixed with the agar before it hardened in all cases, except copper lime dust and copper resinate dust which were dusted upon the surface of the agar plate. Germination counts were made after 20–22 hours.

†Figures refer to the length of pollen tube as compared with the diameter of the pollen grain.

In practically all the trials, even though a considerable percentage of the pollen grains germinated, the tubes were much shorter than in the checks, and in many cases they burst while they were yet short. The experiments with quince and apple pollen were repeated with pear pollen with essentially the same results.

In another series of experiments, materials were sprayed or dusted on the surface of the agar media with the dilutions, and results noted in Table III. The strengths used were those actually tried in the field for fire blight control.

The high germination of the first two, particularly copper sulphate, is somewhat out of line with the other results obtained, and is probably due to the fact that where dusts and sprays were applied to the sur-

face and did not actually come in contact with the pollen grains or the germ tubes. The germ tubes penetrated the agar media and hence at no time were in contact with the toxic substances.

TABLE III—Effect on Pollen Germination of Spraying or Dusting Chemicals on Surface of Culture Medium

Material	Per cent Germination		
	Average	Lowest	Highest
Hydrated lime 3–50	94	72	100
$CuSO_4$ 1–50	44	5	88
Bordeaux 1–3–50	9	4	15
Zinc lime 4–4–50	3	0	5
Copper lime dust 20–80	10	0	42
Copper resinate dust	15	1	62
Untreated check	92	86	95

In another series, different materials were dusted on the surface of the agar among the pollen grains with the results shown in Table IV. Quince pollen was used. The percentages given are the averages of triplicate trials.

TABLE IV—Effect on Quince Pollen Germination of Dusting Chemicals on Surface of Culture Medium

Material	Per cent Germination		
	Average	Lowest	Highest
Cuprous oxide	47	45	49
Pink dust*	6	5	8
Copper carbonate	13	11	15
Copper-lime (20–80)	2	0	4
Untreated check	47	42	53

*Patented product containing 4½ per cent cresol and lime.

Summary

Under the conditions of the experiments herein reported, there was no serious reduction in the set of fruit on bagged hand pollinated branch-units from spraying with various bactericides, except possibly with copper sulphate, bordeaux, and calcium hydroxide. There is some indication that the various dyes applied to branch-units in an orchard where a lack of pollination obtained, decreased the set of fruit. Most of the bactericides tested seriously reduced pollen germination when the substances were mixed with the media upon which the grains were germinated or dispersed on the surface in contact with the pollen grains.

On the other hand, it may be concluded from the field trials that even though the set may be inhibited by the bactericides on a considerable portion of the blossoms sprayed or dusted, usually a sufficient number set fruit to give a satisfactory crop under good polli-

nation conditions. Another possible explanation may be that the various sprays tried do not wet the stigmatic surface but remain in discrete drops between which pollen grains may germinate without contact with the poison. This angle of the problem needs further study.

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Effects of Nitrate Fertilization on Apple Fruits[1]

By Leif Verner,[2] *University of West Virginia, Morgantown, W. Va.*

A FEW years ago persistent reports of discrimination of "the trade" against fruit from apple trees fertilized with nitrogenous materials gave rise to a number of experiments to test the validity of claims that such fruit is inferior in keeping quality. The results of several of these experiments have recently been reported. For the most part the results so far presented have led to a remarkable unanimity of conclusions. For this reason it is considered unnecessary to present at this time more than a summary of a similar study in West Virginia, insofar as it substantiates the currently accepted opinions. In a few instances in which it seems that significant new or additional information may be contributed the results are discussed in some detail. A review of the literature is not undertaken since this has been made recently by Gourley and Hopkins (2), Aldrich (1), and others.

The West Virginia experiments were begun in the fall of 1928 and continued through the storage season of 1932–33. A report on the first two years' work has been presented by Knowlton and Hoffman (3). The present paper, therefore, is confined to a discussion of the subsequent three years' results, in which the study was limited to the varieties York Imperial and Black Twig, grown on Hagerstown clay-loam soil in the Shenandoah Valley region of the state.

Fruit of the York was taken from five trees which had received 8 pounds of nitrate of soda per tree per year, applied about 3 weeks before bloom, since 1928; and from five comparable, adjacent trees receiving no fertilizer during the same period. The trees selected as checks showed marked symptoms of nitrogen deficiency while those chosen from the nitrated block showed evidence of an abundant nitrogen supply. Three pickings were made at weekly intervals, beginning approximately 1 week before the peak of commercial harvest. Random samples of 1 bushel of fruit per tree were taken on each picking date. Records were kept on an individual tree basis throughout the storage life of the fruit under commercial cold storage conditions. The fruit was not wrapped in oiled paper for the prevention of scald except in the case of a duplicate series of samples taken on the second picking date and so treated.

The Black Twigs were picked from three trees receiving 5 pounds of nitrate of soda each per year, about 3 weeks before bloom, since 1927; and from three adjacent unfertilized trees. These trees also showed marked symptoms of high nitrogen supply and nitrogen deficiency, respectively. A single picking was made at the peak of the commercial season.

At the time of picking and at intervals of 3 months or less during

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[2]Located at University Experiment Farm, Kearneysville, W. Va.

the storage period the fruit was tested for firmness by means of the U. S. D. A. pressure tester (4). Readings were taken in the usual manner at 4 points on each of 20 apples from each tree. One reading was always taken on the most highly colored cheek and one on the least colored cheek. Records were taken of diameters of fruit, percentage and intensity of red color, and undercolor. During storage the nitrogen contents,[3] and rates of respiration and transpiration at room temperatures, were ascertained for fruits of the nitrated and non-nitrated trees. The apparatus described by Gourley and Hopkins (2) was used in parallel series for making simultaneous respiration determinations on the two classes of fruit. At the end of the storage period, usually in June, counts of storage scald were taken after several days exposure of the fruit to room temperatures.

The results of this study may be briefly summarized as follows:

1. *Firmness of fruit:*—The apples from nitrated trees were invariably softer at picking time than those from check trees. Thus the averages for 1200 tests of Yorks in each treatment on picking dates in 1931 were 20.6 pounds for fruit from nitrated, and 23.4 pounds for that from non-nitrated, trees. These initial differences decreased rapidly in storage. In 3 months they were negligible. The highly colored cheeks were firmer than those of low color, the averages for these being 22.3 pounds and 21.6 pounds, respectively, in Yorks, and 20.8 pounds, and 20.2 pounds in Black Twigs. Pressure readings on the surfaces intermediate between the most highly colored and least colored cheeks closely approximated the average values for these two combined.

2. *Color:*—There was a marked retardation of red color development in the apples of the nitrated trees in contrast to those of unfertilized trees. A high color percentage and high color intensity were usually associated. Color intensity was recorded on the basis of a scale of increasing intensity from 1 to 4. The percentages of skin surface of Yorks covered by red, and the color intensities, were, from nitrated trees, color per cent 38, color intensity 1.80; from untreated trees, color per cent 68, and color intensity 2.53. Expressed in another way the records show that 80 per cent of the fruit from the check trees, and only 31 per cent from the nitrated trees, were more than 50 per cent red.

3. *Size:*—Nitrate fertilization produced fruits averaging 6 per cent greater in diameter in the York, and 15 per cent greater in Black Twig, than the fruits of corresponding check trees.

4. *Nitrogen content:*—The apples from nitrated trees had slightly higher total nitrogen than those from check trees.

5. *Respiration rates:*—There were no significant differences in the respiration rates of fruits from the nitrated and untreated trees.

6. *Transpiration rates:*—In York the loss of moisture at room temperatures was consistently greater in the fruit of nitrated trees.

[3]The author wishes to express his acknowledgment and thanks to Dr. R. B. Dustman of the Dept. of Agr. Chemistry of the College of Agriculture at Morgantown for the nitrogen analyses of this fruit.

In Black Twig the reverse was true. In neither case, however, was the difference of any significance.

7. *Quality:*—Little has been written concerning the relation of nitrogen fertilization to the dessert quality of apples. St. John and Morris, (6) however, state that the quality of apples as determined by taste is greatly affected by the exposure of fruit and foliage to sunshine and dry air, good exposure favoring the production of high quality while shading tends to retard it. In the present experiments, nitrate fertilization seemed to reduce the quantity or alter the nature of the aromatic substances in such a way as to make the fruit distinctly less appealing. This effect was so pronounced that it was possible at any time over a period of several months, with fruit at room temperature, for a blindfolded person to segregate many mixed lots of apples from nitrated and non-nitrated trees into these two classifications merely by the sense of smell. The differences were especially great in the Black Twigs. There was a corresponding superiority of flavor in the fruit from check trees.

TABLE I—SCALD IN YORKS FROM NITRATED AND NON-NITRATED TREES, 1931 CROP

Date Picked	Treatment	Percent of Surface Covered with Red Color	Intensity of Red Color on a Scale of 1 to 4	Average Undercolor* on a Scale of 1 to 4	No. of Apples Observed	Percent of Scald
Oct. 6	Nitrated trees	24	1.6	1.4	494	85
	Check trees	55	2.1	1.7	562	83
Oct. 14	Nitrated trees	39	1.9	—	397	72
	Check trees	73	2.7	—	564	54
Oct. 21	Nitrated trees	51	1.9	1.6	680	53
	Check trees	75	2.8	2.1	341	33
Oct. 14	Fruit in oiled paper	—	—	—	—	—
	Nitrated trees	39	1.9	—	658	22
	Check trees	73	2.7	—	739	17

TABLE II—SCALD IN YORKS OF HIGH COLOR AND LOW COLOR, 1932 CROP

Date Picked	Description of Fruit	Percent of Surface Covered with Red Color	Intensity of Red Color on a Scale of 1 to 4	Average Undercolor* on a Scale of 1 to 4	No. of Apples Observed	Percent of Scald
Oct. 19	Low color	40	1.7	1.5	309	66
	High color	87	3.2	2.0	254	55
Oct. 29	Low color	42	1.5	1.3	367	29
	High color	95	3.7	2.5	289	27

*Ratings of undercolor were based on the color chart of Magness and others (5).

8. *Storage Scald:*—Table I shows the percentages of scald developed in Yorks, from nitrated and check trees, picked at three different times in 1931. The results are interesting in showing that the greater incidence of scald in the fruit of nitrated trees bears a close relationship only to the stage of maturity of the fruit and not to its color. Thus, the per cent of scald in fruit picked on October 14 from the fertilized trees was no greater than in the fruit picked one week earlier from the check trees, despite the fact that there was still a great contrast in color development. Very low-colored apples picked from the nitrated plots on October 21 scalded less than highly colored fruit from the earlier pickings of the check plot. While the relation of stage of maturity at harvest to scald in storage has long been recognized there has been a general disposition to assume also a causal relationship between low color and scald, whereas the association of these two is probably only incidental. Similar observations were made on early and late pickings of Yorks in 1932 from trees uniformly treated in a well cared for commercial orchard. Highly colored fruit of the early pickings developed more scald than poorly colored fruit of the late pickings. (See Table II). This fact may, or may not, be of importance as an objection to "spot picking," depending upon whether such early harvested fruit goes directly into consumption or is held for a period. Possible relationships of "spot picking" to other characteristics of immaturity deserve consideration.

9. *Shaded and exposed fruit:*—In both nitrated and check trees the most densely shaded fruits were appreciably softer than the exposed fruits from the same trees. The shaded fruits were greener, of lower dessert quality, more susceptible to scald than highly colored fruits picked at the same time, and otherwise resembled fruit especially characteristic of nitrated trees.

Conclusions

Most of the effects of nitrate fertilization so far reported are probably the indirect results of increased leaf areas rather than direct effects of the presence of more nitrogen in the fruit. The shaded fruits of nitrated trees do not differ greatly from similarly shaded fruits of untreated trees, but they constitute a much larger proportion of the total crop. In this indirect manner nitrate fertilization is of great importance in its influence on fruit color and dessert quality. It is of little or no importance in its relation to firmness, nitrogen content, respiration and transpiration rates, and, if allowance is made for proper maturity, to scald susceptibility.

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A Statistical Study of the Effect of Potassium Fertilizers Upon the Firmness and Keeping Quality of Fruits

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THE firmness and keeping quality of fruits from various potassium treatments have been studied at Maryland for the past 6 years. Weinberger (3) has presented a progress report of the work. This paper presents an analysis and interpretation of results secured from an extension of the study. The orchards and methods used were described by Weinberger, excepting the addition of a 25-year-old Williams Early Red orchard at Berlin, Maryland, located on a sandy loam soil.

The report is divided into two parts:

1. A general summary of 6 years data obtained from selected samples of apple and peach fruits.

2. A presentation and discussion of a limited amount of data obtained from random samples which were subsequently separated into various colors and sizes from each fertilizer treatment.

Selected Sample Data

The term "selected" sample as used in this report refers to a sample of fruit chosen for a given size and color, the same type being picked from all fertilizer plots. Thus the effect of treatment upon size and color is eliminated. Any direct effect of fertilizers upon firmness and keeping quality would still be present.

The pressure test data in Table I are averages for each treatment in four orchards, obtained over a 6 year period, and combine variety, location, season, and length of storage period. Each figure represents the average of 450 fruits, each tested three times on pared surfaces.

TABLE I—Average Pressure Test in Pounds of Apples from the Various Treatments

Fertilizer Treatment*	Before Storage	After Storage	Decrease in Firmness
N—only	19.818±.061	13.638±.061	6.180±.086
N—KCl single	19.321±.061	13.164±.061	6.157±.086
N—KCl double	19.428±.061	13.784±.061	5.644±.086
N—P—KCl single	19.309±.061	13.405±.061	5.904±.086
Difference necessary for significance	0.172	0.172	0.243

*Nitrogen was applied equally to all trees. Single KCl means 5 lbs. per tree; double KCl means 10 lbs. per tree; P means 6 lbs. superphosphate per tree.

Combining the data in this manner is legitimate if we assume that varietal responses to KCl treatments will be similar. Each factor of variety, location, season, etc., is present an equal number of times, and it is permissible to make comparisons between the means on the

basis of a standard error obtained in such manner as to remove correlations between these factors. The fact cannot be disregarded, however, that the trees are on the same soil each year, and place or treatment effects will be pyramided in successive seasons. Soil effects, in part at least, have been eliminated by replication of treatments in the four orchards. However, to be certain that the differences are statistically significant, the standard error obtained from the total variance is suggested.

Total variances for one degree of freedom before and after storage were practically the same. The figure proved to be 1.697, from which the standard error of the mean of $\pm$ .061 was obtained. Two times the standard error of the difference ($2\sqrt{2} \times .061$) is 0.172. A difference as great as this would probably not occur by chance alone more than once in 20 similar trials. Consequently this figure may be used to estimate the significance of differences between the mean values for each treatment before and after storage. To the mean values for decrease in firmness the standard error of the difference is applied. To compare these means this standard error is used in the regular formula and applied as outlined above. Two times the standard error of the difference between the differences was found to be 0.243.

At picking time, therefore, (Table I) the nitrogen-only fruits were firmer than those receiving potassium fertilizers. There are no significant differences between the various combinations of potassium with nitrogen or phosphorus. This indicates a direct effect of potassium in hastening maturity of fruits or in affecting firmness in some other manner. A comparison of differences in rate of softening show that N–KCl double treated fruits softened significantly less during the storage period than the fruit from all other treatments.

An explanation would be that only double applications were sufficiently heavy to affect the fruit. However, the writers do not attempt to explain why potassium should hasten softening on the tree, and delay softening during storage, especially since the important factors of size and color were so carefully considered in sampling.

The peach data were treated in a similar manner to the apple data. The procedures used were essentially as reported by Weinberger. The figures in Table II represent the average pressure test

TABLE II—Pressure Test in Pounds of Peach Fruits from the Different Fertilizer Plots

Treatment*	Before Storage	After Storage	Decrease in Firmness
N—only	8.616±.066	4.135±.083	4.481±.105
N—KCl single	8.270±.066	4.144±.083	4.126±.105
N—KCl double	8.439±.066	4.589±.083	3.850±.105
N—P—KCl single	8.532±.066	4.398±.083	4.133±.105
Difference necessary for significance	0.185	0.235	0.296

*Nitrogen applications same on all plots in a given orchard. KCl single means 3 pounds per tree; KCl double means 6 pounds per tree; and P means 4 pounds superphosphate.

of 400 peaches from each fertilizer plot in four orchards, sampled over a 6-year period. Standard errors obtained as with apples and the magnitude of differences required for significance are also given.

Of the before-storage means, those of the nitrogen-only, and complete fertilizer were greater than that of the N–KCl–single plots. No other significant differences exist. The softening rates during storage show that nitrogen-only fruits softened significantly more than all other treatments. As with apples, the presence of potassium in the fertilizer mixture decreased the rate of softening during storage. With peaches the double application decreased softening rather markedly, while the two single applications were practically the same, indicating a rather close correlation between amount of potassium and rate of softening of the fruit during storage.

Random Sample Data

In 1932 and in 1933 random samples of fruit from various treatments were taken to make a more thorough analysis of firmness and keeping quality. The entire crop from 3 to 4 fairly uniform trees in each fertilizer plot was harvested. The fruit was graded into ¼-inch sizes and each size was subdivided into various color classes, depending on the total color range. The number of fruits of each size and color within each treatment was obtained. Fifteen fruits from each were pressure-tested in the usual manner. The results were analyzed by Fisher's Analysis of Variance method, separating the total variance into its various components.

The data presented here was secured from 27 bushels of fruit, which when distributed among three treatments and three soil types did not leave sufficient fruits to make more than one separation for color and one for size. However, the data exemplify the method. The individual fruits (540 in number) were used as the smallest unit, although only averages are given in subsequent tables.

Table III shows the results of the Analysis of Variance computations before storage and Table IV the same material after storage. Table V gives the mean values for each treatment before and after storage along with the rate of softening during storage with the approximate standard errors. The item designated as soil trend (Table IV) was obtained by sampling trees at three different intervals down the row. Any trend in soil fertility would tend to produce a correlated variance provided that soil fertility and firmness are related. From a strict statistical viewpoint, all interactions should be removed from error, but in view of the small number of size and color classes involved in this study, the interactions were left in the remainder variance. The true experimental error is the variance within classes, which in this case is the variance among the 15 apples within each size and color class, and has 504 degrees of freedom.

The results (Table III) show that, at picking time, size, color, and fertilizer treatment all had a significant effect on the pressure test of the fruits. The Z-value given is the one required to denote that such a correlation would not result from chance alone more than once in 20 trials.

TABLE III—Analysis of Variance of Williams Early Red Apples Before Common Storage

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value	
					Found	Necessary
Size	1	48.802	48.802	1.945	1.7273	.6729
Color	1	19.907	19.907	1.490	1.2723	.6729
Treatment	2	26.702	13.351	1.300	1.0823	.5486
Remainder	535	819.744	1.5322	0.2177	—	—
Total	539	915.155	—	—	—	—
Interactions						
Treatment x color	2	19.7451	9.8725			
Treatment x size	2	0.5900	0.2950			

TABLE IV—Analysis of Variance of Williams Early Red Apples After Common Storage

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value	
					Found	Necessary
Size	1	33.8830	33.883	1.7560	1.5878	.6729
Soil	2	39.9791	19.9895	1.4915	1.3233	.5486
Treatment	2	29.9700	14.9850	1.3475	1.1793	.5486
Remainder	534	753.0583	1.4102	0.1682	—	—
Total	539	856.8904	—	—	—	—
Interactions						
Treatment x size	2	4.4695	2.2347			
Treatment x soil trend	4	47.4141	11.8535			

TABLE V—Average Pressure Tests for Williams Early Red Apples from the Different Fertilizer Plots, 1933

Treatment	Before Storage	After Storage	Decrease in Firmness
N—KCl double	22.810±.092	13.438±.088	9.372±.127
N—KCl Single	22.438±.092	13.431±.088	9.007±.127
N—only	22.281±.092	12.936±.088	9.345±.127

The interaction of treatment x color is a significant contribution, showing that the different colors within the different treatments did not respond in the same manner with respect to their pressure tests.

A consideration of the results (Table IV) after storage at prevailing temperatures for 5 days shows that color did not prove to have a significant effect, while soil trend, treatment, and size were significantly differentiated from error.

In comparing the difference among treatments at picking time (Table V) it is evident that the nitrogen-only and the single-potassium fruits were significantly softer than the double-potassium fruits.

A comparison of the amount of softening during storage indicates that the double-potassium-treated fruits softened at about the same rate as the nitrogen-only fruits, and the only significant relationship is that the double potassium fruits softened more rapidly than the single potassium ones.

The fact that these results are quite different from those of the selected sample data cannot be explained.

The peach fruits in 1933 were treated similarly to the apples. The data from three orchards was combined to obtain the advantage of treatment replication. The Belle of Georgia peaches developed brown rot so badly that a test after 4 days in common storage was impossible so one more degree of freedom for location is lost from the after-storage data. The data for before-storage tests were analyzed separately from the after-storage ones, in order to prevent any opposite trends in effect of fertilizer treatment from decreasing the correlated variance due to treatment.

Table VI gives the analysis of variance of the pressure tests of the fruits before storage. Table VII is the analysis of the fruits at the end of a 4-day storage period. Table VIII presents the average pressure tests of the fruits before and after storage, along with the comparative softening rates during the storage period.

The statistical analysis of the peach pressure tests before storage showed a significant effect of treatment, size, color, and location upon the firmness of the fruit. The location item included the effect of the different soil types, and varietal differences, and any differences in maturity of the fruit at time of sampling. The size factor is not extremely significant, although the odds are in excess of 19:1 that the effect is due to size rather than chance alone. The color correlation is very important. The variance correlated with color differences converted into terms of the correlation coefficient gives $r = -.474$. This shows that of the total variability in the pressure test of peaches at picking time, approximately 22 per cent is controlled by the variability in color. This is worthy of attention, considering the many sources of variability. The treatment factor was highly significant, and in comparing the individual treatments on the basis of a common standard error of the difference, it is found that the complete fertilizer and the nitrogen-only are significantly firmer than the N–KCl–single treatment.

The analysis after storage (Table VII) showed that the size correlation drops to an insignificant value, but treatment, color, and location remain important. The number of pounds decrease in firmness during the storage period denotes that the N–P–KCl single and N–KCl single treatments lose about the same amount, but the nitrogen-only fruits decrease nearly 15 per cent more in firmness than the two potash carriers. This indicates that the absence of potassium in the fertilizer mixture causes peach fruits to soften more rapidly during storage. Because of the consistency of this phenomenon in the peaches it seems as though there may be a definite causal relationship which is of considerable significance although possibly of little practical value.

TABLE VI—ANALYSIS OF VARIANCE OF PEACH PRESSURE TESTS BEFORE STORAGE

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value Found	Z Value Necessary
Treatment	2	125.2751	62.6375	2.0715	1.7916	.5486
Size	1	8.9689	8.9689	1.0966	0.8167	.6729
Color	1	360.0163	360.0163	2.9430	2.6631	.6729
Location	2	153.4307	76.7153	2.1665	1.8866	.5486
Remainder	533	934.4365	1.7531	0.2799	—	—
Total	539	1582.1275	—	—	—	—
Interactions						
Treatment x color	2	20.6300	10.3150			
Treatment x location	4	46.4482	11.6125			
Treatment x size	2	4.3577	2.1788			
Size x color	1	4.1989	2.1989			

TABLE VII—ANALYSIS OF VARIANCE OF PEACH PRESSURE TESTS AFTER STORAGE

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value Found	Z Value Necessary
Treatment	2	57.8904	28.9452	1.6835	1.1739	.5486
Color	1	143.2392	143.2392	2.4814	1.9718	.6729
Location	1	629.5957	629.5957	3.2250	2.7154	.6729
Remainder	355	984.6988	2.7738	0.5096	—	—
Total	395	1815.4241	—	—	—	—
Interactions						
Treatment x color	2	11.808	5.904			
Treatment x location	2	23.3902	11.6951			
Treatment x size	2	0.3898	0.1949			

TABLE VIII—MEAN VALUES FOR PRESSURE TEST OF PEACHES BEFORE AND AFTER STORAGE

	Treatment	Before Storage	After Storage	Decrease in Firmness
Before Storage	N—P—KCl single	9.520±.099	4.877±.152	4.643±.181
	N—KCl single	8.452±.099	3.946±.152	4.506±.181
	N—only	9.420±.099	4.140±.152	5.280±.181

In order to fully evaluate the effects of a fertilizer treatment upon the firmness and keeping quality of fruits, it is necessary to use averages which have been weighted according to the number of fruits of the various colors and sizes within each treatment. From the analysis of variance results presented above, it follows that if a given fertilizer treatment materially affects the color or size of the fruit, the weighted average will represent a more correct estimate of the firmness of the fruit, than a simple average obtained from an equal number of fruits from each size and color class.

TABLE IX—AVERAGE PRESSURE TEST OF FRUITS IN THE DIFFERENT SIZE AND COLOR CLASSES BEFORE AND AFTER STORAGE

Class	Before Storage	After Storage	Decrease in Firmness
	Peaches		
ALR	8.12±.114	3.74±.176	4.38±.209
ALG	9.88±.114	4.96±.176	4.92±.209
ASR	8.51±.114	3.64±.176	4.87±.209
SG	10.01±.114	4.94±.176	5.07±.209
	Apples		
ALR	21.99±.106	12.83±.102	9.16±.147
ALG	22.43±.106	13.21±.102	9.22±.147
ASR	22.65±.106	13.51±.102	9.14±.147
SG	22.98±.106	13.52±.102	9.46±.147

TABLE X—A COMPARISON OF SIMPLE AND WEIGHTED AVERAGES OF FRUIT FROM THE DIFFERENT FERTILIZER PLOTS

Treatment	Weighted Average	Simple Average	Weighted Average	Simple Average
		Peaches		
N—P—KCl single	9.92	9.52	5.31	4.88
N—KCl single	8.82	8.45	4.05	3.94
N—only	10.01	9.42	4.33	4.14
		Apples		
N—K double	22.88	22.81	13.47	13.44
N—K single	22.60	22.44	13.60	13.43
N—only	22.52	22.28	13.01	12.94

Table IX presents average pressure test of fruits from each size and color class before and after storage. Table X gives the weighted and simple averages for the pressure test of the fruit from the different fertilizer plots. The weighted averages are all higher than the simple averages. This shows, considering the negative correlation between pressure test and size, and pressure test and color, that small fruits and poorly colored fruits are more numerous than large-sized, and highly colored fruits. This proved to be true. In

general, the weighted averages are quite highly correlated with the simple averages. The only exception is in the case of after-storage results of the peach fruits receiving the complete fertilizer. There the weighted average is proportionally higher than the simple average. This is explained by the preponderance of small green peaches having a high pressure test.

If the correlation between the firmness of the fruit before storage and its firmness after storage is removed by obtaining the actual loss in firmness of each size and color class there is a tendency for the green fruits to soften more than the red fruits (Table IX). The differences are consistent, although not all are statistically significant. This agrees with the findings of Morris (2) in the case of apples, and with Blake *et al.* (1) in the case of peaches. Morris also found that highly colored apples were firmer at picking time, than poorly colored ones. This work does not agree on that point, probably due to the fact that a summer variety was used, rather than a fall or winter one.

A summary of this paper yields the following points:

1. Data obtained from selected samples of apples and peaches over a 6-year period shows a tendency for the lack of potassium in the fertilizer treatment to make the fruits firmer at picking time, but to soften more rapidly during storage.

2. The method of picking a random sample and then determining the various factors affecting the firmness of the fruit by Analysis of Variance, is presented as an effective means of attacking such a problem.

3. The weighted average is discussed as a means of more fully evaluating the effect of fertilizers upon firmness and keeping quality.

4. The absence of potassium in the fertilizer treatment caused all peach pressure tests analyzed, whether by random or selected sample, to soften more rapidly in storage. This phenomenon did not hold in the case of the Williams Early Red apples sampled in 1933.

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The Cross-Transfer of Water in Mature Lemon Trees

By J. R. FURR and C. A. TAYLOR, *U. S. Department of Agriculture, Pomona, Calif.*

THE practice of irrigating alternate sides of the tree row on successive irrigation dates is now fairly common in many of the Southern California citrus orchards. This method is used in the belief that more economical application of water can be made than by irrigating both sides of the row on the same date, that it is desirable to maintain a high soil moisture content in part of the root zone at all times to avoid danger of extreme desiccation of the trees during hot weather, and that danger of plow sole formation is decreased by having dry middles for traffic through the grove.

Growers have questioned the authors regarding the readiness with which water is transferred from the roots on the wet side of the tree to the branches on the dry side.

Though Auchter (1) has shown that cross-transfer of water takes place readily, most of his work was done with relatively young trees. It seemed possible that cross-transfer might be accomplished with greater difficulty in old trees. Many mature citrus trees show very pronounced ridges of tissue leading up from main roots to main branches, suggesting that rather definite segregation of the major part of the younger xylem may exist. Auchter's experiments in which the roots were removed from one side of the tree showed that the moisture content of the tissue on both halves of the plant was about the same, but that the moisture content of the whole plant was reduced as compared to a plant with a complete root system. The object of the experiments reported in this paper was to determine whether cross-transfer of water occurs readily in mature citrus trees, and to obtain some idea of the degree of stress for water produced in the tree as a whole by removing part of the root system.

The work reported in this paper was done in October, 1933, on 30-year-old lemon trees on the American Fruit Growers' Corona plantation,[1] Corona, Calif. Nine adjoining trees in one row were selected for the experiment. Every third tree was left untreated. The soil was carefully removed from the crown of the remaining six trees, so that all roots were exposed at the point of union with the trunk. These trees had 5 to 11 roots ranging from 30 to 40 cm in circumference 1 foot from the trunk. These large roots probably provided over half of the feeder roots of the tree. The treatments were purposely made very severe in the belief that if any restriction in cross-transfer existed it would be easier to detect than would be the case if the water supply to the tree were not greatly reduced.

On each tree at the beginning of the experiment and before any treatments were given, 30 fruits about 15 cm in circumference were tagged. These fruits were measured with a steel tape at frequent

[1]The authors are indebted to Mr. A. C. Barnes, Manager, American Fruit Growers, Corona plantation, for his co-operation in this study.

intervals during the course of the experiment. Two observers, working independently, measured all fruits and at once checked by a third measurement any apparent discrepancies in their observations. The circumference measurements were converted to fruit volume by reference to a conversion table prepared as follows: The relation between circumference and volume of the fruits was established for a large number of fruits within the size range encountered in this study by measuring the circumference with a steel tape and determining the volume by displacement. These data were plotted on cross section paper and the conversion table made up from the mean curve.

It had been found in other work that the diurnal change in fruit volume seemed to be correlated with the suction force of the leaves. That is, on days favoring a high transpiration rate the fruits began to shrink early in the morning and continued to lose in volume until late afternoon. During the night, as the tree made up its water deficit, the fruits swelled again. In normal trees this change in fruit volume may amount to 6 or 8 per cent of the volume of the fruit on warm days when the soil is moderately low in moisture content. In trees in soil with little water available the deficit may not be entirely made up over night, as shown by the fact that a very large increase in volume occurs the first night following irrigation.

Changes in fruit volume cannot be used as an index to transpiration rate, but rather as an index to water deficit. This method, therefore, has the same fault as that of determining the moisture content of tissue samples. However, it is adapted to making large numbers of observations at frequent intervals, and measurements are made of the same fruits throughout the experiment.

The findings reported in this paper are based upon over 6000 measurements. Each measurement was separately converted from circumference to volume. The original measurement of each fruit on October 21 was taken as 100, and each subsequent measurement expressed in percentage of the original. The mean value of the 30 fruits measured on each tree was calculated for each period of measurement, and in the case of trees D, E, F, G, and H, the mean values for the fruits over cut roots and those over uncut roots were calculated separately. These data have been carefully analyzed and a representative part is presented in the following pages.

In the different treatments various portions of the root systems were severed from the tree by making a saw cut through the roots about 1 foot from the trunk, as follows:

Tree A, B, C—Untreated checks.

Tree D—All roots cut except 2 large ones near soil surface Oct. 22, 8:45 a. m.

Tree E—All roots cut except one large one leading out to northwest from the trunk, Oct. 22, 9:45 a. m.

Tree F—All roots cut except one large one leading out to north from the trunk, Oct. 21, 9:50 a. m.

Tree G—All roots on south half of tree cut Oct. 21, 9:45 a. m.

Tree H—All roots cut except one large one leading out to south from the trunk, Oct. 22, 9:15 a. m.

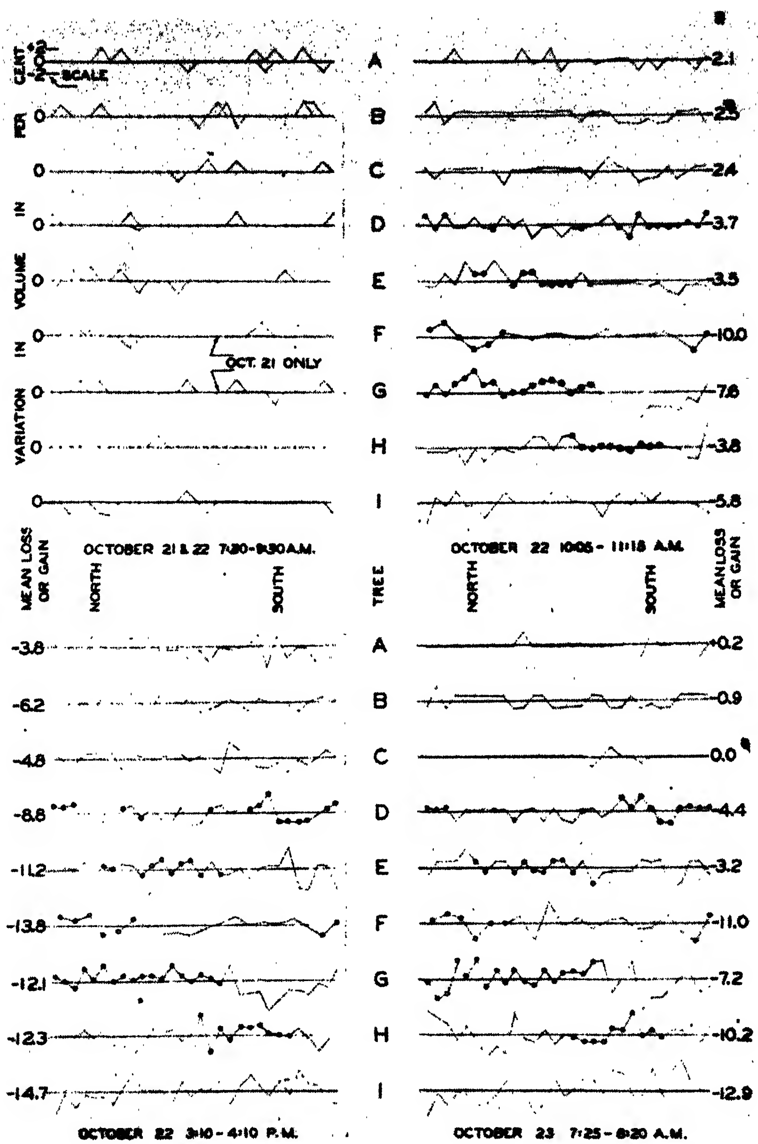

FIG. 1A. Effect of cutting different roots on the water supply to various portions of the tree as indicated by the loss or gain in size of fruits on six treated trees and three checks. The plotted points represent the individual variation in volume of 30 fruits spaced about uniformly around the tree with north and south as shown in the graph. On treated trees, points representing fruits directly over uncut roots are enclosed in small circles. Loss or gain is expressed as a percentage of the volume on the morning of October 21.

Tree I—All surface roots cut Oct. 22, 9:00 a. m. (8 small roots—4–8 cm in circumference—which appeared to extend downward into subsoil remained uncut).

If there is any appreciable restriction of the cross-transfer of water throughout the tree, then soon after a large root is cut there should be a marked shortage of water in the branch to which the root had been directly connected and the branches directly connected to undisturbed roots ought not to be affected to any large extent. If the cross-transfer occurs readily, then the whole tree should be affected uniformly and to a degree depending on the proportion of roots cut. The data have been examined to test this hypothesis and a graphical presentation of the finding made in Figs. 1A and 1B. In these figures, the variations in volume of each fruit are shown in per cent of the fruit volume on October 21. The trees are listed in order from A to I. The points on the graphs represent fruits spaced nearly uniformly around the tree, starting from a point in the northeast quadrant of the tree and proceeding counter-clockwise around the tree. North and south are indicated on the graphs.

The plotting for October 21 and 22, 7:30 a. m. to 9:30 a. m. in the upper left of Fig. 1A is for three independent rounds of measurements before cutting roots. The early mornings were foggy with no sun during these measurements and the variations show the degree of error in the measurements. Readings of the circumferences of fruits were taken to the nearest millimeter and this was the largest difference in these measurements. One millimeter in circumference on the size of fruit used represents about 2 per cent in actual fruit volume. The first reading on the morning of October 21 is used as a reference and all subsequent variations expressed as a percentage of this original volume. In the case of trees F and G, only the readings on the morning of October 21 are given, since roots were cut on these two trees between 9:30 a. m. and 10:00 a. m. on that date.

In the upper right of Fig. 1A, the results of a round of measurements taken between 10:05 a. m. and 11:15 a. m. on October 22 are given. The mean loss in volume of the 30 fruits on each tree is given by the numerical values on the right, and the variation of each fruit from the mean is plotted to the same scale as used in the 7:30 a. m. to 9:30 a. m. measurements. This same scale is used throughout in Figs. 1A and 1B. Roots were cut after the first morning measurement on October 22 except on trees F and G, which were cut on October 21. The points enclosed in small circles represent fruits on branches directly above uncut roots on the treated trees, D to I. The remaining points for these trees are for fruits on branches directly above cut roots. In the case of tree I, surface roots were cut entirely around the tree. It will be noted from the numerical values that the mean loss in volume was least on the three checks and greatest on trees F and G, which had roots cut a day before the others. Except for tree G, there is no significant difference between fruits on branches over cut and uncut roots. In the case of tree G, the shrinkage of the fruit on branches over uncut roots is

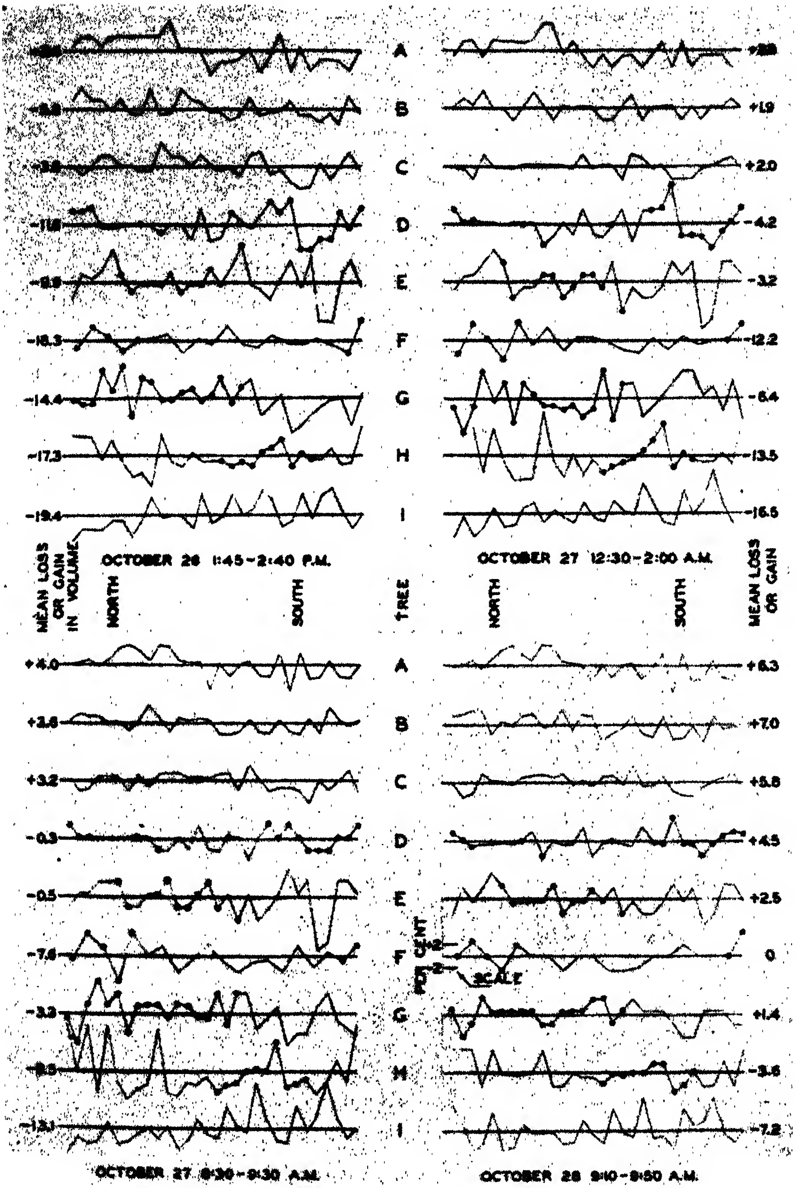

FIG. 1B. Recovery following irrigation on October 26 and 27 of trees used in root-cutting experiment as indicated by the loss or gain in size of fruits. The loss or gain is expressed as a percentage of the volume on the morning of October 21. The same scale and notations are used as in Fig 1A.

definitely less than for fruit over cut roots. However, it should be noted that the cut roots were on the south side of the tree and that the check trees also show the greatest shrinkage of fruit on the side of the tree facing the sun.

The results of a round of measurements taken between 3:10 p. m. and 4:10 p. m. on October 22 are given in the lower left of Figure 1A. The mean loss in volume of the fruits on each tree is given by the numerical values on the left and the individual points show the variation of each fruit from the mean. Although there had been a large loss in volume in each case, the only significant difference between fruits over cut and uncut roots appears in tree G.

The sun dropped behind the hills at 4:15 p. m. and, with the reduction in transpiration during the night, the trees recovered in moisture content and the fruit swelled again. The fruit on the three checks recovered to about the same volume it had on October 21 and the treated trees recovered in varying amounts, the least recovery being shown by tree I, which had all surface roots cut. Here again the only significant difference appears in tree G, and the difference is not as great as on the afternoon of the day before.

The soil around all trees except check tree A, which was next to an irrigation standpipe contained little available moisture. There was no visible evidence of wilt on any of the check trees, but the leaves rolled in varying degrees on all treated trees, with tree I showing the greatest distress.

Water was applied in furrows around all trees on October 26 and 27. The soil is a gravelly loam and water penetrated rather slowly, so that there was little effect on the trees on the 26th. This is shown by the round of measurements between 1:45 p. m. and 2:40 p. m. on October 26, the results of which are shown in the upper left of Figure 1B. The severe degree of stress in the treated trees F to I is shown by the large losses in fruit volume amounting to as much as 19.4 per cent in tree I. The variation in the volume of fruits is independent of position over cut and uncut roots. The difference for tree G as between cut and uncut roots is not appreciably greater than the differences between the north and south sides of the check trees.

The trees recovered rapidly during the night of October 26. A round of measurements was made between 12:30 a. m. and 2:30 a. m. on October 27, with results as shown in the upper right of Fig. 1B. There is no significant difference shown in the rate of recovery of fruits over uncut roots as compared to fruits over cut roots.

Further recovery is shown by the results of a round of measurements taken between 8:30 a. m. and 9:30 a. m. on October 27. (Lower left of Fig. 1B). In the lower right of Fig. 1B, the results of a round of measurements on October 28, 9:10 a. m. to 9:50 a. m. are given. By this time the fruit on all trees except that on H and I had recovered to, or exceeded the volume obtained from the original measurements made on October 21. No significant difference is found in the rate of recovery of fruits whether over cut or over uncut roots.

It seems evident from the foregoing discussion that the position of a fruit in relation to cut or uncut roots had very little influence on its changes in volume. The conclusion is therefore reached that there is a ready cross-transfer of water throughout the tree. However, the removal of roots had a profound influence on the water supply to the tree as a whole. These results indicate that where irrigation water is applied on alternate sides of the tree on successive irrigation dates the cross-transfer of water will be accomplished very readily, even if the trees are mature and have pronounced ridges of tissue extending from main roots to main branches. The results also suggest that, when portions of the root zone are permitted to reach the wilting point, the available supply to the whole tree is reduced.

This experiment and other work not reported here show that even in normal lemon trees in moist soil, a daily water deficit occurs. The mean losses in volume of fruit on the three check trees were 3.8, 6.2, and 4.8 per cent on October 22. The maximum temperature on this date was 92 degrees F. Apparently the loss of water by transpiration from the leaves sets up a gradient toward the leaves throughout the tree and water is pulled from the fruits to the leaves where transpiration is occurring. The degree of shrinkage apparently depends on the magnitude of the water deficit in the leaves. If there is any advantage in maintaining the water deficit at a minimum, it would seem desirable to maintain readily available moisture in the whole root zone during the season when transpiration is high. In the late fall, during the winter, or in early spring, the demands of transpiration can be met by irrigating less than 100 per cent of the soil mass, for example, by irrigating in alternate middles.

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Fertilizers as Related to Leaf Area in Apple Production[1]

By E. L. Overholser and F. L. Overley, *State College of Washington, Pullman, Wash.*

IN 1927 a fertilizer experiment was started with 18-year-old Jonathan apple trees. The trees were 26 feet apart on the diagonal in fairly uniform soil of the Ephrata series of the fine sandy loam type, underlain with water-washed gravel on the second bench of soil above the Columbia River in the East Wenatchee district.

Larsen (1) in chemical studies of the soils of these fertilizer plots concluded "that the soil dealt with cannot fix fertilizer elements by exchange reactions to any appreciable degree and for this reason residual effects of several years of fertilization may be expected to be small. Fertilizers added to this soil must be used the same season that they are applied, otherwise they will gradually be lost in seepage waters."

Soil Management and Fertilizers Applied

The soil management of the orchard previous to the initiation of the experiment was as follows: in 1918 about 8 pounds of a 6–10–4 complete fertilizer were applied per tree; during the winter of 1919 and 1920 a "fair spread" of stable manure was applied. In the springs of 1922 and 1924 about 6 pounds of nitrate of soda were applied per tree; in 1925 and 1926 about 6 pounds of nitrate of soda were applied in the irrigation ditches just after thinning, about July 1; and in 1925 about ¾-ton of lime was applied per acre. The orchard had been clean cultivated until 1922 when it was seeded to a cover crop of alfalfa and thereafter has been disked in the spring each year, with the exception of 1933. The cover crop at present consists of some alfalfa but is generally composed of mixed grasses and weeds uniformly distributed over the orchard land. The irrigation has been that commonly employed and sufficient water has been applied by means of the rill system during each growing season to supply the needs of the trees for normal growth and production.

The experimental fertilizers annually applied per tree since 1927 were equivalent to 1 pound of actual nitrogen in the form of sulphate of ammonia (5 pounds), 1 pound of actual phosphoric acid in the form of superphosphate (6 pounds), and 2.5 pounds of potash in the form of muriate of potash (5 pounds).

Tree Response

The tree responses (4) to the application of mineral fertilizers are shown in Table I. The average annual terminal growth made by the trees has tended to be increasingly greater in all plots receiving nitrogen alone or in combination with phosphorus or potassium or

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with both than that made by the trees in the check plot. Phosphorus and likewise potassium when applied alone has tended to result in increasingly less terminal growth as compared to that made by the check trees. When phosphorus and potassium have been applied in combination without nitrogen the average terminal growth has been comparable to that made by the check trees. Likewise, notwithstanding somewhat larger yields, the size of individual apples from trees receiving nitrogen has been maintained as compared with the check trees. The application of phosphorus alone, and potassium alone or in combination without nitrogen, however, has resulted in smaller sized apples as compared to those from the check trees. This is true notwithstanding an average smaller crop per tree.

Leaf Area Relationship

It appeared that these responses to the application of fertilizers may be related to the average leaf area borne per tree. Accordingly the leaves on a representative tree of each plot were counted and the average area of individual leaves was computed, and thus the approximate leaf area carried by the trees of each plot determined as shown in Table I.

TABLE I.—Fertilizers as Related to Leaf Area in Apple Production

Fertilizers Applied	Total Computed Leaf Area (sq. in. per tree) 1933	Average Terminal Growth (ins.) 1927 to 1933	Total Average Weight of Apples per Tree (lbs.) 1929 to 1933	Average No. Fruits per Standard Box 1929 to 1933	Per cent Red Overlay Color 1929 to 1933
N	1,546,310	7.8	693	153	61
NPK	1,519,168	7.6	601	158	64
NP	1,447,541	7.2	718	147	65
NK	1,393,554	7.1	730	143	63
PK	1,002,046	5.2	537	166	77
Check	960,280	5.5	542	156	79
P	766,933	3.7	348	169	87
K	434,052	3.4	419	178	84

On the whole there appeared to be a fairly definite relationship between the average leaf area per tree and the average terminal growth, average yield, and average size of individual apples. Those trees receiving nitrogen had a relatively large leaf area, those receiving PK without nitrogen being somewhat comparable to the check trees and those trees receiving P alone and K alone having a relatively small leaf area. It must be recognized that leaf area per tree in 1933 possibly resulted from increased shoot growth during preceding years, which from the more lateral buds each year thereafter produced young spurs, and the succeeding years more bearing spurs. In this manner increased shoot growth in 1927 to 1931, inclusive, could have produced an increase in the 1933 crop. Further-

more, N could have produced better functioning of existing spurs, possibly, by affecting leaf number per spur, as well as actually increasing the set per spur.

Nevertheless, these data indicate that the response to the application of fertilizers may be a result of the increasing or decreasing of the total leaf area per tree. It is possible, despite the rather common view concerning the role of K or P in photosynthesis that, where P or K is applied alone the amount or efficiency of the chlorophyll of the apple leaf may also be lowered in addition to the reduction in total leaf area available. At any rate, the application to the soil of this experimental plot of P or K alone, either through their effect upon the soil or the direct effect upon the tree, had a marked (and apparently an increasingly) depressing effect upon the average annual terminal growth, yield, and size of individual apples.

The per cent of color, however, seemed to increase notwithstanding a lower leaf-fruit ratio as compared to the trees receiving nitrogen. The data in Table I show also that the average per cent of red overlay color during the seven-year period was lower in fruit from trees receiving nitrogen than in fruit from trees receiving no nitrogen, notwithstanding the relatively larger leaf area of the trees from the plots receiving nitrogen. It is possible that greater sunlight striking the apples in these trees with the reduced leaf area may have been a more important factor in favoring the development of red color (3) than was the reduced leaf-fruit ratio, (2) in opposing this development. It is also likely that the total functioning leaves on trees not receiving N were developed and available earlier each season than were the leaves on the trees that received nitrogen. Hence, the former would be manufacturing available plant food over a correspondingly longer period of time during the growing season.

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A Fertilizer Trial With Bartlett Pears

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IN 1928 a block of Bartlett pears at Lakeport, California, at an elevation of 1,350 feet, was selected for this study. The trees were mature, over 25 years, planted 22 feet apart on a gravelly clay soil. The soil is deep and the subsoil is rather heavy. It was at one time lake bottom. The proportion of clay decreases toward the upper end of the gentle slope on which the orchard is situated. The trees are not irrigated. The annual rainfall averages about 36 inches, most of which falls between October and May. Frosts in the spring are not uncommon, the crop being destroyed in 1932 and reduced somewhat in 1928, 1931, and 1933.

The part of the orchard used consisted of 41 rows. The odd-numbered rows 1–41 were guard rows. Every fourth row (2–6–10–), 10 in all, were checks. Treatments were, in order, NPK, N, K, P, and PK applied to rows 4–8–12, etc., all treatments duplicated. All plots contained 10 trees each. In the spring of 1928, several weeks before blossoming, applications of fertilizer were made to the respective plots at the rate of 5 pounds of $NaNO_3$, 5 pounds of KCl, and 10 pounds of treble superphosphate (about 45 per cent P_2O_5). All material was broadcast. These same amounts were applied in 1929, and annually thereafter at the rate of 10 pounds of each material to a tree. A total of 50 pounds each of $NaNo_3$ and KCl, and 60 pounds of superphosphate, was applied per tree in the six seasons. All applications were made during the latter part of the dormant season.

Blossom counts were made at full bloom and fruit counts in June, after the major drop had occurred. Yield records were obtained for each tree in August. Leaf samples for analysis were taken from shoots 1 to 2 feet long, the basal leaf being used for analysis from 10 to 12 shoots per tree in all cases. All samples were composites of all of the trees in the respective plots.

The percentage of fruit set varied greatly from year to year, largely as a result of varying degrees of injury by spring frosts. Counts were made only on the first 10 plots. In every year in which records have been taken, the trees receiving N have averaged somewhat greater in per cent set. The plots receiving complete fertilizer and nitrogen only, were averaged. The two check plots outside these two, and the one between them, were averaged. These averages were compared. The figures for the average of two fertilized plots and of their three nearest checks for the 5 years the counts were made are 12.4, 8.5, 11.7, 8.9, and 9.1, and 9.8, 5.2, 8.9, 6.6, and 5.7 per cent respectively. There has been no consistent difference between the other treatments and the checks.

The yields of fruit have been higher on those plots which have received nitrogen than the remaining plots. The average increase in total yield of each of the plots receiving N over the average of the two adjacent checks are NPK, 19.6 per cent; N, 26.2 per cent; NPK,

30.7 per cent; and N, 24.8 per cent. Each of the remaining treated plots averaged slightly less than the average of their two adjacent check plots, the differences not being significant in any case. Since these results are strictly in agreement with many other trials in different places, the data are not presented here, but are available to any one who cares to communicate with the writer. These data also show decreased yields for the PK plot in the first half and in the second half of the block.

Analyses of leaves only were made. It is, therefore, possible that both P and K might have been absorbed and have remained in other parts of the tree. With this qualification in mind, the data obtained from analyses of leaf samples seem to bring out again the fact that even rather large amounts of potassium or phosphate added to the surface soil give no assurance of absorption of these materials by the plant on some soil types. The analyses for 1933, which are presented in Table I, show that 60 pounds of phosphate per tree may be fixed by the soil and give no increased absorption by the tree, and 50 pounds of KCl per tree causes only a doubtful increase to be absorbed. No economical method of overcoming this difficulty has as yet been found, although McKinnon and Lilleland (3) have done so experimentally. The leaves from the plots showing lower yields, due to change in soil type, show lower P and K contents also.

TABLE I—Percentage of N, P, and K in Pear Leaves Collected in June, 1933, on a Dry Weight Basis

Treatment	N	P	K	P/N
Check	2.04	.253	1.41	.124
NPK	2.37	.205	1.09	.086
N	2.35	.202	.97	.086
K	1.99	.283	1.68	.142
Check	2.04	.253	1.24	.124
P	1.98	.243	1.05	.123
PK	2.01	.211	1.08	.105
Check	2.11	.202	.75	.096
NPK	2.29	.202	1.11	.088
N	2.19	.191	.77	.087
K	2.02	.218	1.11	.108
Check	2.13	.211	.76	.099
P	2.19	.204	.93	.093
PK	1.89	.191	.83	.101

At this time it seems that only nitrogen can be given a place in the fertilizer program for trees on these soils. It has been shown (4) that trees grow well and produce abundantly with a very low level of phosphate and potassium in the soil if other conditions are satisfactory. The conclusion seems justified that any soil having high fixing power for these materials, that is so deficient in either of them that normal growth and profitable fruiting is not possible, should not be planted to orchard. If an orchard is growing on such soil it would probably be wise to remove the trees or abandon it. This conclusion, of course, would not necessarily apply to orchards in

regions having a different climate, or where the trees have feeding roots in the surface soil.

An interesting point that is brought out by these data is the effect of nitrate on the absorption of phosphate, and on the P/N ratio in the leaves. In spite of considerable variation in the absolute values, the leaves in those plots receiving N tend to be higher in N and lower in P than other plots. The ratios of P to N also show considerable variability except in the case of plots receiving N. In those plots the ratios .086, .086, .088, and .087 are remarkably constant and are the lowest found. This low ratio of P to N is also found in leaves of a variety of fruits grown on other soils. Kinman and Proebsting (2) find the same relationship in peaches, apricots, and prunes in the Santa Clara Valley. Pears in another part of the same valley yield the following results: Check, N, 2.53 per cent; P, .229 per cent; P/N, .090; N plot, N, 2.63 per cent; P, .194 per cent; P/N, .074. Samples from an apricot orchard near Winters show the following: Check, N, 2.15 per cent; P, .365 per cent; P/N, .177; N plot, N, 2.57 per cent; P, .277 per cent, and P/N, .108. Anderson (1) has obtained similar results in South Africa with citrus.

It is an interesting fact in this connection that in spite of decreased P absorption when N is used on deciduous trees that are growing on soil low in P, no evidence of P deficiency has been found as evidenced by tree growth or yield. The N plots have been the only ones to give increased yields where any differences have been noted.

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The Third Year of Growth Experiments with Pin Oaks

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THE general plan and results of the first 2 years of these experiments have been described in papers presented before the Society in 1931 and 1932. All pin oak trees used were raised from the same seed lot, grown on the same field and selected for their uniformity after 5 years of growth. The paired plot system was used in laying out the experiments. Love's modification of Student's Method was used in analyzing all results. The present report deals with the results at the end of the third year (1933) after transplanting.

FERTILIZERS

Because all the trees were under sod, pronounced growth was obtained in 1932 from both nitrogen alone (ammonium sulphate) and nitrogen plus phosphorus (ammo phos). In the spring of 1933, these trees, with exceptions to be noted, were again fertilized. Eight ounces of ammonium sulphate were applied to each tree receiving nitrogen only, and 12.8 ounces of "ammo phos" to those trees receiving nitrogen plus phosphorus. Applications were made 2 ounces at a time starting May 5, and the remainder at 2-week intervals. The fertilizer was applied in holes 12–18 inches deep and about 12 inches from the base of the trunk. As a result, increased growth of the fertilized over the unfertilized trees was to be expected. The outstanding point of interest was the decidedly significant increase in growth of trees receiving nitrogen plus phosphorus over trees receiving nitrogen alone. This effect was noted in 1932 also but not then reported.

TABLE I—EFFECTS OF FERTILIZERS ON GROWTH (IN FEET PER TREE)

Soil Type	No. Trees	Ammonium Sulphate I	Ammo Phos II	Check III	Odds in Favor of		
					I over III	II over III	II over I
			Growth in 1933				
Gravelly clay..	16	20.2	26.1	12.16	104:1	525:1	124:1
	20	27.73	42.05	18.81	171:1	9999:1	1666:1
Average......		24.37	35.00	15.24	9999:1	9999:1	9999:1
			Growth in 1932				
Gravelly clay..	18	14.28	19.58	9.51	475:1	9999:1	3332:1
	24	16.60	19.15	11.87	237:1	587:1	not sig
Average......		15.60	19.40	10.69	9999:1	9999:1	9999:1

Though the odds vary each year, the odds for the grand total remain the same. Other workers (1, 2, 3) have shown that phosphorus, when applied to the soil surface, is held within the upper 1½ inches. This may explain why applications of phosphorous have not

increased growth in so many cases. The soil in question is a good fertile loam, and even unfertilized trees appear to be in good condition. Phosphorous may have some effect on the form of nitrogen taken up by the plant, or it may increase root growth or in itself increase top growth.

Unfortunately, no trees were treated with phosphate alone, but this will be done next spring. Also trees will be treated with nitrates alone and other experiments will also be started in an effort to determine, if possible, why nitrogen plus phosphorus increases growth more than nitrogen alone.

RESULTS

Residual effects of fertilizers:—Since fertilizers increased growth so markedly in 1932, some of the trees then showing marked response were not fertilized in 1933. The results (Table II) show that fertilizers applied in 1932 had a marked effect on the growth of these trees in 1933. This applies to both the N and the N plus P treatments.

TABLE II—EFFECTS OF PREVIOUS FERTILIZATION ON 1933 GROWTH
(No Trees Fertilized in 1933)

	No. Trees	Growth (Feet per Tree)			Percentage Increase	
		1931	1932	1933	1932	1933
Fertilized........	30	3.00	17.14	28.07	804*	56*
Unfertilized......	30	2.90	8.82	14.42	445*	18*

*These figures were obtained by adding the individual percentage increases and then averaging the total.

Secondary growth:—Secondary growth was measured in the same way as previously. Primary growth was complete by about June 15, when the total 1933 growth made by all trees was measured. All trees were again measured October 1, and the difference between the measurements for October 1 and June 20 was taken as secondary growth.

TABLE III—AVERAGE TOTAL GROWTH PER TREE (IN FEET)
BEFORE AND AFTER JUNE 20, 1933

Soil	Planted	Fertilized before June 20		Fertilized after June 20		Unfertilized		Residual trial	
		Before	After	Before	After	Before	After	Before	After
Gravelly	Spring	19.71	3.54	——	——	9.76	1.67	16.85	3.59
Gravelly	Fall	10.39	6.39	6.29	4.40	9.92	3.69	23.13	7.53
Clay...	Spring	23.25	16.15	——	——	11.14	2.59	17.49	14.91
Clay...	Fall	17.64	11.09	18.06	7.70	13.09	5.50	20.21	10.82
Average		16.57	9.10	10.77	5.66	10.78	2.91	18.94	9.06
Percentage of primary growth		55		52		27		47	

From the table it is obvious that a comparatively large amount of secondary growth was made by those trees in the Residual fertilizer experiment.

Pruning:—At the time of planting (1930–31) some of the trees in this experiment were left with a certain total length of branches all along the trunk, and others were left with a similar amount of branches all emerging near the top of the tree. It was reported in 1932 that trees with branches left all along the trunk grew considerably better than those with branches only at the top. The same was true in 1933.

TABLE IV—TOTAL GROWTH PER TREE (IN FEET) OF TREES PRUNED WITH BRANCHES GROUPED AT THE TOP OR DISTRIBUTED ALONG THE TRUNK

Time of Planting	Branches at Top I			Branches Along Trunk II			Odds in Favor of II over I		
	1931	1932	1933	1931	1932	1933	1931	1932	1933
Fall.....	3.88	17.83	18.28	3.20	26.65	23.80	notsig.	525:1	262:1
Spring...	2.56	13.33	14.50	3.57	20.35	20.54	notsig.	344:1	666:1
				Total Odds			95:1	9999:1	1999:1

This experiment was tried also on 20 *Cornus kousa chinensis* plants. These plants had a total branch length of about 36 inches when selected as uniform plants in the nursery. They were potted and placed in the greenhouse during the early spring of 1933. Ten of the plants were stripped of buds and small branches along the main stem except for the top 6 inches. A similar amount of buds and small branches was taken from the ten remaining plants except that the buds and branches left were distributed along the trunk. Those with branches left only at the top grew an average of 20.4 feet while those with branches along the trunk grew an average of 36.0 feet, with odds over 9999:1 in favor of the latter. Consequently, stripping these young shade trees in order to give a clean trunk for some distance from the ground, inhibited growth for the first few years after transplanting.

Diameter measurements:—At the start of these experiments, the diameter of the oak trunks measured about 1 cm. The increase in diameter for the first year was about 1 mm, too small to be measured accurately. Consequently no great emphasis was placed on early diameter readings. In 1933 the increase in diameter averaged from 4 to 9 mm, which was sufficiently large to be measured accurately. The diameter and length of all fertilized trees were compared with similar measurements on all the correspondnig check trees. The correlation coefficient between actual elongation of twigs and diameter increase was found to be .8258 ± .0238, a decidedly positive correlation.

Planting experiments:—Differences in growth of trees planted in various ways, though significant in 1932, were not markedly significant in 1933.

CONCLUSIONS

The third year of these experiments with pin oaks shows that:

1. A mixture of nitrogen plus phosphorous (ammo phos) gave better growth than nitrogen (ammonium sulphate) alone when applied in holes in the ground, under sod.
2. Fertilizer applied in the spring of one year, increased the growth that year and probably in the following year.
3. An increase in secondary growth is, of course, caused by spring and early summer fertilizer application.
4. Trees which had branches distributed along the trunk made greater growth than those with branches only at the top.
5. There was a positive correlation between branch elongation and diameter increase.
6. Planting practices (as previously described by the author in the 1931 Proceedings) had no marked effect on the growth during 1933.

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The Replaceable Potassium Content of Orchard Soils in Maryland as Affected by Potassium-Carrying Fertilizers

By R. F. CHANDLER, JR., *University of Maryland, College Park, Md.*

A STUDY of the replaceable potassium content of the various apple and peach orchard soils on which experimental fertilizer trials were located, was made in Maryland during the years 1931 and 1932. The objects of this study were to determine the normal amount of replaceable potassium in the soils, and the effect of the addition of potassium-carrying fertilizers upon this fraction of the soil potassium. As the same soil types were included in the apple and peach orchards, only the data from the former are reported in this paper.

Soil samples were secured from three successive 6-inch layers, under three fertilizer treatments, namely, no potassium, 5 pounds KCl per tree per year, and 10 pounds KCl per tree per year. Four different soil types were involved. The samples were obtained during the summer of 1931, after four annual applications of fertilizer had been made. The extreme dryness of the soil precluded the use of either a soil auger or a soil sampling tube, but the samples were obtained satisfactorily by means of a two-handled post hole digger. The samples were dug from just within the outer spread of the branches of the trees, so as to get the full effect of the fertilizer applications. After air-drying the soil, the replaceable potassium content was determined by leaching 100 grams of the soil with 750 ml of normal ammonium acetate solution, evaporating an aliquot to dryness, driving off the ammonia with heat, and determining the potassium in the residue by means of the sodium cobalti-nitrite method (4). The results include any water-soluble potassium, as the samples were not extracted with water before the determination was made. However, the water-soluble potassium fraction is extremely small in nearly all soils, seldom reaching a value in excess of 10 p. p. m.

The soil types studied ranged from a clay loam in western Maryland to a loamy sand on the Eastern Shore. Extreme variations in the replaceable potassium content existed, and in order to determine the factors contributing to this variability, all four soil types were considered together as a population, and the data analyzed by means of Fisher's Analysis of Variance. A condensed summary of the results is presented in Table I, and the analysis of variance with the mean values is given in Table II (a and b). The 143 degrees of freedom for the total can be accounted for by the analysis of four samples from each 6-inch layer within the three treatments on the four soil types.

The effect of soil depth is quite striking. An inspection of Table II (b) indicates that the top 6-inch layer is very significantly differentiated from the two lower layers, but the difference between the 6- to 12-inch and 12- to 18-inch layers is not quite large enough to be classed as significant. The several soil types and the various

TABLE I—REPLACEABLE POTASSIUM CONTENT OF THE DIFFERENT ORCHARD SOILS AT DIFFERENT DEPTHS, AND UNDER VARIOUS TREATMENTS

Treatment	Depth	Hagerstown Clay Loam	Penn Gravelly Loam	Sassafras Fine, Sandy Loam	Sassafras Loamy Sand
No potassium	0–6	152	70	81	36
	6–12	83	36	36	36
	12–18	74	39	33	33
5 pounds KCl per tree for 4 years	0–6	231	318	308	103
	6–12	93	63	100	105
	12–18	62	50	38	113
10 pounds KCl per tree for 4 years	0–6	823	529	290	105
	6–12	336	161	205	78
	12–18	202	50	51	71

TABLE II (a)—ANALYSIS OF VARIANCE OF REPLACEABLE POTASSIUM IN THE ORCHARD SOILS

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value	
					Found	Necessary
Soil depth.	2	972,695.77	486,347.88	6.5475	1.7637	.5486
Treatment	2	954,726.77	477,363.38	6.5377	1.7539	.5486
Soil type	3	488,133.49	162,711.16	5.9977	1.2139	.4787
Depth x treatment	4	451,758.00	112,939.50	5.8131	1.0293	.4319
Treatment x soil type	6	557,889.50	92,981.58	5.7198	0.9360	.3706
Depth x soil type	6	372,204.83	62,034.14	5.5174	0.7336	.3706
Treatment x depth x soil type	12	336,219.00	28,018.25	5.1199	0.3361	.2804
Within classes	108	1,558,888.40	14,434.15	4.7838	——	——
Total	143	5,692,515.76	——	——	——	——

TABLE II (b)—MEAN VALUES FROM THE ABOVE ANALYSIS WITH THEIR STANDARD ERRORS

Soil Types	K in ppm	Treatment	K in ppm	Soil Depth	K in ppm
Hagerstown Clay Loam	237±20	No K	54±17	0″–6″	260±17
Penn Gravelly Loam	151±20	KCl 5 lbs.	134±17	6″–12″	113±17
Sassafras Fine Sandy Loam	122±20	KCl 10 lbs.	253±17	12″–18″	68±17
Sassafras Loamy Sand	78±20	——	——	——	——

treatments react differently in the three soil layers, producing the two interactions of depth x treatment, and depth x soil type. The cause for these interactions is seen in Table I. The clay loam soil causes a much greater accumulation of potassium in the upper layer, than the loamy sand, while the gravelly loam and fine sandy loam soils occupy an intermediate position. This difference is most logically explained by the colloid content of the various soils. The fixation of potassium in the upper layers of soil is quite proportional to the colloidal content of the soil types studied. The colloidal matter, both organic and inorganic, is most abundant in the upper 6-inch layer, accounting in part for the high potassium content of that layer. In addition, the fact that all applied potassium must pass through the upper layers before it can reach the lower ones, cannot be disregarded. If the proper kind of colloidal material were present in sufficient amount, in the upper layer, one would expect all of the applied potassium to be absorbed immediately, and remain in such a state until hydrogen or other cations replaced it, causing it to temporarily go into solution.

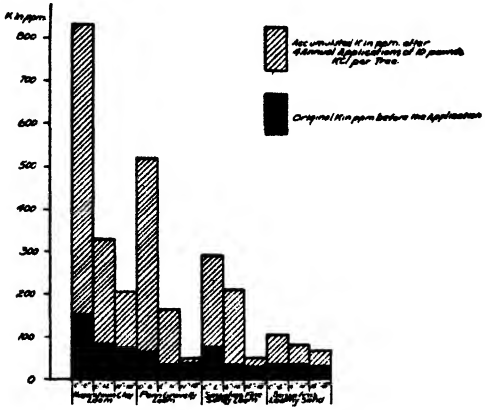

FIG 1. Replaceable potassium in the different layers of the various soil types, before and after fertilizer applications.

An important cause of the higher replaceable potassium content of the upper layer in the plots where no potassium has been applied, is that plant tissues high in potassium content, are continually being deposited in this layer. The potassium liberated upon their decomposition contributes to the supply of replaceable potassium. This potassium may have originated from lower layers, and thus constitutes an upward movement of soil potassium. Also the fact that these decomposing plant materials increase the organic colloidal material in the upper layer, should be considered.

The effect of treatment is very marked in all cases (Table II b). Fig. 1 presents the 10 pound per tree application results graphically. An inspection of this chart indicates that the potassium accumulates greatly in the clay loam soils, to a less degree in the gravelly loam and still less in the fine sandy loam and loamy sand. The colloidal relationships discussed above are doubtless responsible for these differences. The interaction of treatment x location explains the differences statistically. It is of interest to note from Fig. 1 that the gravelly loam and fine sandy loam are not far different when no fertilizer has been added, but after the application of 10 pounds per tree

of KCl, the gravelly loam contained a greater amount of potassium in the upper 6-inch layer, while the fine sandy loam contained more in the lower levels than the former. In general the 10-pound application caused a greater accumulation than the 5-pound, although this did not hold true with the loamy sand. This could be accounted for by the presence of soil heterogeneity with respect to colloid content.

Although a large amount of the applied potassium is absorbed in the upper few inches of soil, it is of interest to note that when the different soil types were considered separately, and Fisher's "t" comparison made, the two fertilizer applications had caused all three layers to be significantly heavier in replaceable potassium than the same layers of the plots which received no potassium fertilizers. Also, the second and third 6-inch layers were significantly higher in the case of the 10-pound application than in the case of the 5-pound treatment. This indicates that with the soil types included in this study and under the given fertilizer treatments, potassium is moving down through the soil to some extent. Probably the exchange capacity of all soils studied was lower than that of the soil reported by McKinnon and Lilleland (2), where practically no applied potassium moved down from the surface. In this connection, the method of injecting potassium into the soil as proposed by the above workers, has been employed at the Maryland Station with very satisfactory results, as far as increasing the replaceable potassium in the lower layers is concerned.

Considering the soil types as a whole, regardless of treatment or layer, the Hagerstown clay loam is significantly higher in replaceable potassium than the remaining types. There is not a significant difference between the Penn gravelly loam and the Sassafras fine sandy loam. The gravelly loam is significantly higher than the loamy sand, while the fine sandy loam is not quite significantly differentiated from the loamy sand, although the probability of such a difference occurring due to chance alone would be only once out of seventeen trials.

In general, it can be said that the soils studied were originally rather low in replaceable potassium. From a comparison with the data presented by Lilleland (1) and Wallace and Proebsting (5), one would expect to find some signs of potassium deficiency in the trees growing on certain of these soils. No such signs have been noted.. However, as Proebsting (3) points out, plants seem to be capable of utilizing a certain amount of non-replaceable potassium. Also, the potassium- supplying power of a soil is not necessarily correlated with its replaceable potassium content.

Summary

The four soil types studied varied greatly in their replaceable potassium content.

The replaceable potassium decreases, generally, with an increase in depth, but the change is most marked, when comparing the first two 6-inch layers.

Applications of potassium result in a considerable fixation of replaceable potassium in the upper layers of all soils. Soils of an extreme sandy nature do not exhibit this phenomenon to a very great degree. Apparently this fraction of the soil potassium is a function of the colloid content of most soils. However, a significant increase in replaceable potassium in the lower layers is caused by surface fertilizer applications.

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A Study of the Effect of Various Potassium Carrying Fertilizers Upon the Growth and Yield of Apples and Peaches

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THIS paper presents a summary of the growth and yield data from the potassium fertilizer plots which have been under study at Maryland for the past 6 years. The experimental set-up is as described by Weinberger (1), except that a Williams Early Red orchard, about 25 years old, is included.

The circumference of all trees was measured each year in centimeters. As no measurements were obtained in the spring of 1928, only 5 years of growth data are presented. Estimated or actual yields were obtained each season that a crop was produced on the trees.

For the purpose of analysis, all plots receiving a double amount of potassium (10 pounds KCl per tree or equivalent for the apples, and 6 pounds KCl or equivalent for the peaches) were grouped together whether the potassium was applied as the sulfate, chloride, or double salt of magnesia. Likewise the single amounts (half double amounts), and complete fertilizer plots, and the nitrogen-only plots were grouped so as to have four fertilizer treatments in all. Since the number of trees making up the different treatments was unequal, no effect of replication within one area could be determined. However, replication over a wide area was obtained by considering all peach data as well as all apple data as a population. Also, the effect of averaging many trees in one orchard, reduced the variability.

The circumference measurements are treated on the basis of the average trunk increase per tree, per treatment, per year, as the smallest unit. The yield data are averaged for all seasons for each treatment in the different locations. The seasonal effect could not be considered, as yield records were not obtainable every year. In the case of Elberta peaches, at Hancock, no yield data are presented as there were many crop failures due to frost.

The analysis of variance for the peach growth data is presented in Table I (a) and the mean values with their standard errors are shown in Table I (b). The same material for the apple trees is presented in Table II (a) and (b). Any insignificant correlations or interactions are included in the remainder variance.

TABLE I (a)—Analysis of Variance of Peach Trunk Circumference Increment Data (Cms)

Source	Degrees of Freedom	Sum of Squares	Variance	½ loge	Z Value	
					Found	Necessary
Season.......	4	10.6423	2.6606	0.4892	1.2137	.4632
Location.....	3	33.7626	11.2542	1.2061	1.9306	.5073
Season x location....	12	26.3186	2.1932	0.3919	1.1164	.3255
Remainder...	60	13.9653	0.2327	—0.7245	——	——
Total......	79	84.6888	——	——	——	——

TABLE I (b)—MEAN VALUES OF PEACH TRUNK CIRCUMFERENCE INCREMENT DATA

Treatment	Average Cir. Increase (Cms)	Variety and Location	Average Cir. Increase (Cms)	Season	Average Cir. Increase (Cms)
N—K—Single..	2.90±.11	Elberta at MountAiry	4.07±.11	1929	2.73±.12
N—K—Double	3.01±.11	Elberta at Berlin	2.70±.11	1930	3.59±.12
N—P—K......	3.19±.11	Elberta at Hancock	2.35±.11	1931	2.66±.12
N—Only......	3.24±.11	Belle of Georgia at Salisbury	3.22±.11	1932	3.41±.12
				1933	3.02±.12

TABLE II (a)—ANALYSIS OF VARIANCE OF APPLE TRUNK CIRCUMFERENCE INCREMENT DATA (CMS)

Sources	Degrees of Freedom	Sum of Squares	Variance	½ $\log_e$	Z Value	
					Found	Necessary
Season.......	4	6.1912	1.5478	0.2674	0.9804	.4632
Location.....	3	3.4672	1.1557	0.0713	0.7843	.5073
Season x location....	12	37.7555	3.1462	0.5726	1.2856	.3255
Remainder...	60	14.5108	0.24185	—0.7130	——	——
Total......	79	61.9247	——	——	——	——

TABLE II (b)—MEAN VALUES OF APPLE TRUNK CIRCUMFERENCE INCREMENTS

Treatment	Average Cir. Increase (Cms)	Variety and Location	Average Cir. Increase (Cms)	Season	Average Cir. Increase (Cms)
N—K—Single..	2.76±.14	Williams, Berlin	2.84±.14	1929	3.60±.15
N—K—Double	2.91±.14	Stayman, Salisbury	2.87±.14	1930	2.55±.15
N—P—K—Single	2.65±.14	York, Hancock	2.82±.14	1931	2.64±.15
N—Only......	2.58±.14	Rome, Frederick	2.36±.14	1932	2.57±.15
				1933	2.29±.15

The fertilizer treatments, as a whole did not contribute sufficiently to the total variance of the trunk circumference increments to be classed as significant. (Tables I (a) and II (a)). However, when individual treatments are considered separately, peach trees receiving no potassium grew significantly more than those receiving only a single amount of potassium. Other potassium treatments did not affect growth, consequently it would seem logical that the above difference is one resulting from chance, even though such a difference would be expected to result from treatment 21 out of 22 trials.

The location factor is extremely significant in the case of the peaehes, and quite so in the case of the apples. The factors contributing to

this source of variability are too numerous to receive discussion here, but such factors as soil management, soil type, age of tree, variety, etc., are included.

The factor of season is quite important, showing that weather influences the growth of fruit trees materially. Probably the amount of rainfall is the most important weather factor. The extremely significant interaction of season x location would indicate that the trees on the several soil types responded differently in the various seasons. Since the water-holding capacity of the different soils varies markedly, it would seem reasonable that a given rainfall might be limiting in one orchard, and not in another.

The yield data for the peaches and apples are presented in Tables III and IV, respectively. The results were treated by Fisher's analysis of variance method but as only one source of variability proved to be a significant contribution to the total variability, the figures are not presented here.

TABLE III—YIELD DATA FOR PEACHES, EXPRESSED IN AVERAGE BUSHELS PER TREE PER YEAR

Variety and Location	N-Only	N-K Single	N-K Double	N-P-K Single	Location Averages
Elberta, Mount Airy.....	2.54	2.88	3 41	3.35	3.04±.13
Elberta, Berlin...........	2.35	2.18	2.62	2.40	2.39±.13
Belle of Georgia, Salisbury	3.21	3.23	3.23	2.99	3.16± 13
Treatment averages......	2.70±.15	2.76±.15	3.08±.15	2.91±.15	——

TABLE IV—YIELD DATA FOR APPLES EXPRESSED IN AVERAGE BUSHELS PER TREE PER YEAR

Variety and Location	N-Only	N-K Single	N-K Double	N-P-K Single	Location Averages
York, Hancock..........	5.47	3.86	5.66	5.22	5.05±.28
Rome, Frederick.........	2.45	3.80	3.42	3.19	3.22±.28
Williams, Berlin.........	2.85	3.43	3.69	3.90	3.47±.28
Stayman, Salisbury......	5.75	5.06	5.75	5.56	5.53±.28
Treatment averages......	4.13±.28	4.04±.28	4.63±.28	4.47±.28	——

The fertilizer treatments did not have a significant effect upon the yield of either peaches or apples.

The location factor was important in its influence upon yield. This is not surprising, considering the many factors which could influence the productivity of the trees in the different orchards.

In conclusion, potassium-carrying fertilizers over a 6-year period, have not had any consistent effect upon the growth and yield of apple and peach trees in Maryland. The effect of the location of the orchard, and the prevailing weather conditions during the different seasons, have influenced the performance of the trees.

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Little-Leaf or Rosette of Fruit Trees, III

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Soil Treatment

In preceding papers (2) we have shown that it was the zinc in impure ferrous sulphate that cured little-leaf trees. Independently, others have found this to be true (1) (3). It was shown also that, because of the very great ability of soils in the interior valleys of Pacific Slope states to render zinc unavailable, more zinc sulphate is required to correct a tree than would be contained in the amount of impure ferrous sulphate required to correct it; also that the nearer some roots the material was placed and the less soil it covered the more effective a given amount would be.

Experience this year has shown that the smaller the area a given amount covers, *i. e.* the nearer the trunk it is applied, the longer the benefits last. Even in the soil with the least fixing power of any we have studied, the benefit from 3 pounds of zinc sulphate applied all within a foot of the trunk of a large peach tree is lasting longer than that from 9 pounds spread over all the soil in a radius of 9 feet from the trunk. The benefit from just enough zinc sulphate to correct a tree completely is not as lasting as that from just enough impure ferrous sulphate to correct it. For example, in this soil the latest leaves to form in the second summer after a treatment were mottled on trees corrected with 9 pounds of zinc sulphate, but not on trees corrected with 40 pounds of impure ferrous sulphate, containing not more than 2.4 pounds of zinc sulphate.

In a soil with a much higher fixing power, trees treated with 5 pounds of zinc sulphate each in a small basin around the trunk, or 9 pounds on the surface in a small area around trunk, seemed completely cured in the first summer after the treatment, but these, and even trees treated with as much as 25 pounds applied in the same way, showed bad little-leaf in the second spring after the treatment. Trees, in the same orchard, treated with 75 to 110 pounds of impure ferrous sulphate, containing not more than 4.5 to 6.6 pounds of zinc sulphate, appeared to be in as good condition at the end of the second summer as those treated with any amount of zinc sulphate up to 25 pounds were at the end of the first summer.

Because of the varying fixing power of soils for zinc, and perhaps because of the varying depths from the surface to roots, results with soil applications of zinc sulphate have not always been as dependable as results with impure ferrous sulphate. In the same orchard, with trees having apparently the same severity of little-leaf, some trees show little or no response to an amount of zinc sulphate that completely cures others.

Ferrous sulphate applied with zinc sulphate seems to keep some of the zinc available to the trees longer. In the laboratory it was found that zinc fixed in a soil could be released with a calcium sulphate solu-

tion. Calcium sulphate is considerably cheaper than ferrous sulphate, and large quantities of it would probably be less injurious to the soil. Plats in a walnut orchard were arranged to study the effect of calcium sulphate and zinc sulphate. Trees that received only calcium sulphate were clearly not benefited; trees that had calcium sulphate applied on the zinc sulphate, both salts in narrow trenches around the trunks, or both salts on the surface over all the soil within 7 feet of the trunks, showed more striking recovery than trees treated with zinc sulphate alone. In fact, 5 pounds to the tree of zinc sulphate under 10 pounds of calcium sulphate seemed to give better results than 15 pounds of zinc sulphate alone. Results of soil treatment with walnuts are more uncertain than with stone fruits, possibly in part because of the dilution caused by the greater distance from roots to the growing points, but perhaps more largely because of the greater depths, and the greater variation in depth, to the first roots of fair size.

To see whether ammonium sulphate would hold zinc available in soils, peach trees were treated with zinc sulphate alone, 4 to 8 pounds each, and others with 4 pounds of zinc sulphate mixed with 4 pounds of ammonium sulphate, in circular trenches 30 inches from the trunks with some, on the surface 30 inches from the trunks with others. Four pounds of zinc sulphate alone was enough to cure the trees in some parts of the orchard so that, in the first year, there could be no visible benefit from the ammonium sulphate, except for the increased growth caused by the nitrogen supplied. In other parts of the orchard, however, 4 pounds of zinc sulphate alone was not enough to prevent some mottling, and the trees that had ammonium sulphate mixed with the zinc sulphate were free from mottling.

If neither calcium sulphate nor any other harmless substance about as cheap will hold zinc available and thus reduce the amount required, obviate the uncertainty of results, and prolong the benefit, the use of zinc sulphate applied through the soil is not very promising for most semi-arid districts.

Soil treatment on one or two sides of a tree:—Peach trees bad with little-leaf were treated with 6 pounds each of zinc sulphate in shallow trenches 3 feet long and 2 feet from the trunks, in some cases all in a trench on one side of the tree, in some 3 pounds each in two trenches on opposite sides of the tree, and in some 6 pounds surrounding the tree. Treatment on one side caused very striking benefit on that side but little or none on the opposite side. Treatment on two opposite sides of the tree usually caused recovery on all sides, but on some trees a branch or two did not seem to obtain enough zinc. The results were not uniform enough to supply conclusive evidence as to whether or not it is better for the zinc sulphate to surround a tree than for it to be in trenches on two sides. It is, of course, much more convenient to apply on two sides only, especially when furrow irrigation is practiced, for then the two inner furrows can be deepened a little along each side of the tree and the material placed there.

Injury from soil application of zinc sulphate:—We had no injury to deciduous trees from soil application of zinc sulphate made when the leaves were off, until the winter of 1932–33, when in the San

Jaoquin Valley there were only rather light showers at any time, not enough to dilute the zinc sulphate greatly but enough to take it to some of the roots in high concentration. In cases where this was not diluted by irrigation in early spring, some trees lost many of their first leaves. However, they soon put out new leaves, and uniformly showed striking recovery.

A fair number of deciduous trees have been badly injured, and a few killed, by summer treatment. Further, to make summer treatment safe it is necessary to use so much water that too much of the zinc sulphate is washed to deeper soil and fixed. Results are, therefore, uncertain. We think deciduous trees should have soil treatment only when the leaves are off.

When orange trees in Tulare County were treated in the winter of 1931–32, the material was placed on the surface of the soil, for some trees all within 3 feet of the trunk. Excellent results and very little injury tended to follow. In the winter of 1932–33, many trees were treated by this method. The light rain of that winter took the material to the shallow orange roots in high concentration, and a large percentage of the trees were killed or injured badly.

Some of the less severely injured trees, and some injured in Kern County the year before, showed rather interesting symptoms. Sometimes where a root of fair size was killed, on the upper side at least, there was a strip of dead wood up the trunk and following the lower side of a branch out to branchlets not more than 1 inch in diameter. Some sapwood under these streaks was killed. This, of course, gives no conclusive evidence as to the tissues in which the zinc moved, but it seems to us most probable that it got into the outer sapwood through the dead roots and was carried with rather little dilution in the transpiration stream, killing the cells, including cambium and perhaps inner phloem, fairly close to the vessels carrying it.

The new leaves on such injured branches were not strikingly small or in rosettes characteristic of little-leaf, but were a little smaller than the normal leaves of orange fruiting branchlets. They were usually not mottled, and when there was a suggestion of mottling it was the reverse of little-leaf, the lack of chlorophyll being along the veins instead of in the areas between them. The pale green color did not seem identical with that of leaves on nitrogen-deficient trees. It seemed a clearer green, a little less golden. Branches injured in Kern County in the winter of 1931–32 still, at the end of 2 years, show this small, sparse, pale foliage on what new growth they make.

In some foliage taken June 16, 1933, about 18 months after treatment, from the worst branch on one of these trees that had received 20 pounds of zinc sulphate in a basin containing some exposed roots, there was 130 p. p. m. of zinc; the small stems to which these leaves were attached contained 230 p. p. m. Leaves taken at the same time from trees cured, but uninjured, by about 5 pounds in such basins, contained only 30 p. p. m. of zinc.

Possible danger from zinc in soil:—When we first began to use zinc sulphate, we were not certain that there would not be reason for

spreading it over all the soil, possibly applying it in fertilizer. It seemed advisable, therefore, to see what effect rather large quantities of zinc in the soil might have on the trees and on some other crops. In February 1932, 100 pounds of zinc sulphate was spread around one peach tree and 50 pounds around another, each over an area 20 feet square. The soil was very sandy, having the least fixing power of any we have studied. The trees were completely cured of little-leaf and showed no bark injury, but the foliage has not been healthy. In color and form it resembled a mild form of the leaf injury just described for oranges. However, these trees are in a section of the orchard where nematodes injured the roots 6 feet deep or deeper. Nematodes cause such an appearance of the leaves; and so we cannot be certain that the leaves on these trees have, or have not, been injured by excess of zinc.

In the spring of 1933, sunflowers were planted along the row between the trees where there had been no leaching except by about 8 inches of rainfall, mostly in showers that did not penetrate more than a few inches. The sunflowers came up and grew well between the other trees, but in the soil that received so much zinc sulphate, they died while still under the surface. Basins 8 inches deep were made for these strips and water kept in them for 2 hours, long enough to use about 2 acre feet. Sunflowers were planted again and died before they were more than an inch high. The land was flooded as heavily again and sunflowers planted. This lot grew a little taller before dying. After a third such flooding, sunflowers grew 6 to 8 inches high and died. This experience may not indicate that repeated treatment of trees through the soil with only enough zinc to correct little-leaf is apt to injure the soil for other crops. The leaching during the two or more years between treatments may be enough to prevent accumulation. Naturally, the method which gives best results in other respects, applying the zinc in a small area near the trunks, also avoids danger to the remainder of the soil.

Soil treatment with zinc oxide:—In the sandy soil at Delhi, having the smallest fixing power for zinc of any we have studied, zinc oxide was applied in trenches 18 inches from the trunks of the trees; four trees had 20 pounds each, one had 10 pounds, and one had 40 pounds. Two of those with 20 pounds each, and the one with 10 pounds, had ammonium sulphate in equal quantities mixed with the zinc oxide. None of the trees showed any injury from the treatment, and all showed improvement by June, and apparently complete recovery during the summer, though all were so bad with little-leaf at the beginning that they had been killed back to some extent. Evidently some of the zinc oxide is changed to a soluble compound by substances or organisms in the soil, or by the tree roots.

Spraying for Little-Leaf

Following the few experiences mentioned before (2), spraying has been tried on several kinds of trees growing in a number of soil types, but because soil type seems to have little or no influence on results from spraying, they are combined in the table. Zinc sulphate

has been used with lime, with only a spreader such as blood albumen, and in lime-sulphur solution. The amount of zinc sulphate used was from 5 to 30 pounds in 100 gallons of water. When lime was used, it was hydrated lime. In the following enumeration of results "12–12–100" means: 12 pounds of zinc sulphate and 12 pounds of hydrated lime in 100 gallons of water. Results seem to be different for different times of application, perhaps in part because of varying amounts of moisture available to dissolve zinc dried on the leaves following an application. In the enumeration of results that follow, therefore, times of application are designated as "spring," meaning after growth starts and before May 15; "summer", May 15 to September 1; "autumn," September 1 to leaf fall, with citrus, September 1 to December 1. The term "nearly dead" means the upper main parts of all main branches have died back so that the foliage in spring is all in sparse little-leaf rosettes and there are few, if any, summer shoots bearing normal leaves. "Very bad" means that all spring foliage is in little-leaf rosettes and foliage on the summer shoots, though normal in size, is badly mottled. Such a tree may live many years or may die in a few years.

Responses of Different Kinds of Trees to Spraying with Zinc Sulphate in Different Seasons

Spring 1932

Peach:—Phillips Cling, 4 trees, very bad, 12–12–100. Striking improvement within a month, but by July 1 the latest leaves to form were badly mottled. Sprayed again May 29, 1933, and showed improvement, but by the end of the summer were bearing badly mottled leaves. Another tree, nearly dead, sprayed first at the same time, showed some improvement. Sprayed again October, 20–10–100. Showed considerable improvement, spring 1933. Sprayed again May 29, 1933. Growth of 1933 much better than 1931 or 1932, but mottling on leaves formed in late summer.

Summer 1932

Peach:—Phillips Cling, 7 trees, very bad, 12–12–100. No evidence of improvement in summer of 1932 or spring of 1933. Sprayed again May 29, 1933. No improvement.

Plum:—Santa Rosa, 3 trees, very bad to nearly dead, 12–12–100. No improvement 1932 or 1933.

Apricots:—2 trees, very bad, 12–12–100. Striking improvement. Healthy leaves on new growth cycle summer 1932 and spring 1933.

Grape:—Alicante, 15 vines, nearly dead, 12–12–100. In 3 weeks, healthy shoots that became 4 to 5 feet long by autumn, though checks made no growth after time these were treated. New shoot growth spring 1933 better than checks, but leaves mottled.

Walnuts:—22 trees, bad to very bad, 12–12–100. Three trees certainly not benefited; 2 had some leaf injury from the spray and were apparently benefited slightly; 3 others seemed benefited, but effect uncertain, owing to variation in severity of little-leaf from growth cycle to growth cycle.

Oranges:—Navel, 12 trees, moderate to rather bad, 8–8–100 or 8 pounds of zinc sulphate in lime-sulphur solution. No apparent spray injury. Mottled leaves receiving the spray became greener, but new leaves formed in 1932 were mottled, some slightly less so than on unsprayed trees. Much less mottling on new leaves formed in 1933, though spraying was not repeated.

Autumn 1932

Peach:—Phillips Cling, 4 trees very bad, 20–10–100. No apparent injury to foliage from spray. In spring of 1933, buds that without the spray would have opened into rosettes of little-leaves, formed shoots bearing leaves of normal size, free from mottling, but by May 29 newest leaves were mottled. Two of these sprayed again May 29; healthy except for some mottling late in summer.

Peach:—Elberta, 8 trees, very bad, 30–0–100 with a little blood albumen. Also treated with 4 pounds zinc sulphate in trench near trunk. In spring of 1933, developed shoots with normal leaves instead of little-leaf rosettes, and trees held crop of fruit. On 3 trees adjacent to each sprayed tree, and having had the same soil treatment but no spraying, buds developed little-leaf rosettes; nearly all fruit dropped, but healthy leaves without mottling were showing by June.

Two other trees in this lot had the same autumn spraying but no soil treatment; they opened normal leaves in spring and held the crop, but the newest leaves were mottled by June. All untreated trees adjacent to each tree sprayed or treated through soil showed bad spring little-leaf and mottling of all summer leaves.

Apricot:—Royal, 11 trees very bad to nearly dead, 30–0–100, with blood albumen. No leaf injury from spraying was observed. In spring 1933 showed improvement and fruit became larger than on untreated trees, but improvement less than with peaches. Some mottling on later, summer growth cycles.

Apricot:—Royal, 5 trees, very bad to nearly dead, old corral soils, 16–16–100. In spring of 1933, some improvement, but many little-leaf rosettes. Mottling in late summer.

Plum:—Santa Rosa or Beauty, 1 tree, bad, 16–16–100. In spring 1933, normal leaves instead of little-leaf rosettes, remained healthy all summer.

Walnut:—Payne and other varieties, 40 trees, bad to very bad, 30–0–100 and blood albumen. Spray injured leaves and hastened their falling. In spring or summer of 1933, no convincing evidence of benefit.

Walnut:—Payne, 2 trees, very bad, 30–0–100, with blood albumen. No spray injury. No benefit in spring or summer of 1933.

Apple:—Gravenstein, mild to very bad, 20–0–100 and some blood albumen. Strong evidence of improvement early in spring and in summer of 1933, but, because of variation in severity of little-leaf among trees, evidence is not beyond question.

Oranges:—Navel, 19 trees, 10–0–100. Mottling entirely corrected on leaves sprayed. Growth in spring cycles and others during summer of 1933 free from mottling. Growth increased but slightly, if at all.

Winter, 1932–33

Peach:—Phillips Cling, 3 trees, bad, 20 per cent zinc sulphate solution spread over bark of all parts, including twigs. Cured at beginning of spring growth and free from mottling all summer.

Peach:—Phillips Cling, nearly dead, 33 per cent solution of zinc chloride painted on the lower 4 feet of the central stem of a large branch. Recovery in the shoots within a few feet of the treated part and improvement, but not complete recovery, in shoots farther away.

Oranges:—Navel, 335 trees, bad to very bad, 10–0–100 on a few, others 10 pounds of zinc sulphate in 100 gallons of 2 per cent, 4 per cent, or 6 per cent lime-sulphur. Mottling almost completely corrected on leaves sprayed and almost completely prevented on growth after the spraying. Growth strikingly increased on some, not measurably increased on others.

Spring 1933

Peach:—Phillips Cling, 5 trees, very bad, 20–10–100. Improvement showed earlier than from winter soil treatment, but hardly as early as from winter treatment through holes in the trunk. Leaves formed as late as June 16 showed mottling.

Peach:—Elberta, 8 trees, very bad, had been treated in soil in autumn 1932, 20–10–100. Spraying caused improvement before trees showed improvement from soil treatment, but not early enough to hold the crop.

Two trees without soil treatment, sprayed at this time, showed the same early improvement, but leaves formed as late as June 30 were mottled.

Apricot:—Royal, 9 trees, bad to very bad, 16–10–100, no leaf injury from spray. Improvement, but not so great as with peaches.

Apricot:—Royal, many trees, moderate to very bad, 20–8–100. Improvement rather striking; seemed greater than that on apricots sprayed in autumn. Caused improvement in size of fruit on bad trees.

Plum:—Santa Rosa, May 10, 50 trees, bad to very bad, 15–5–100. Considerable amount of leaf injury and abscission caused by spray. Fruit not injured. New growth of healthy leaves that were nearly free from mottling throughout summer.

Walnut:—Payne and others, 20 trees, bad to very bad, 15–6–100. Some evidence of benefit, but not conclusive, owing to variation in severity of little-leaf from growth cycle to growth cycle.

Oranges:—Navel and some Valencia, 464 trees, bad to very bad, 10 pounds zinc sulphate in 100 gallons of 2 per cent or 4 per cent lime-sulphur. When done before May, about the same improvement as followed winter spraying.

SUMMER 1933

Grapes:—Carignane, bad to very bad, July 21, 15–3–100. Shoot growth had ceased, but in 2 weeks lateral buds were pushing new shoots bearing leaves free from mottling. Such growth was not made on untreated vines.

Walnut:—Payne and others, 60 trees, bad to very bad, 12–5–100, June. Some evidence of benefit, but not conclusive, owing to variation in severity of little-leaf from growth cycle to growth cycle.

Oranges:—More than 1400 trees, 10 pounds zinc sulphate in 2 per cent lime-sulphur. Benefit seemed less than when done before May.

Most of results from spraying oranges were supplied by Mr. J. C. Johnston, Assistant Farm Advisor, Tulare County. Results from some plats were supplied by Mr. N. D. Hudson, Assistant Farm Advisor, Kern County.

On peaches and apricots, and possibly on plums, almonds, and apples, spraying in autumn with a zinc-lime mixture 16–6–100 or stronger tends to cause growth, in the following spring, of shoots bearing normal leaves, from buds that would otherwise open into tufts of little leaves. On trees seriously enough affected to bear mottled leaves on the summer growth, one autumn spraying will not prevent mottling of leaves formed after the first 6 to 8 weeks of growth, but it will cause fruit to set better and, with apricots and early peaches at least, will cause it to develop normally instead of being small and misshapen.

On trees that show little-leaf enough in spring to reduce the crop, but bear normal leaves on the summer growth, results with a few trees suggest, but do not prove conclusively, that one autumn spraying may prevent all little-leaf and cause normal bearing. Perhaps more than half the little-leaf of plums is of this kind. We do not know, for any deciduous fruit, whether or not one spring spraying a year on trees that show bad little-leaf in spring, but bear normal summer leaves, would keep them healthy. Apparently a tree may show this form of little-leaf in one year and be normal in another. Spraying in spring during the little-leaf season would enable one to reduce expense by spraying only little-leaf trees. In autumn it may

not always be possible to tell which trees will show little-leaf the next year.

Spraying peaches and apricots in spring, during the most pronounced little-leaf symptoms, with zinc-lime 10–5–100 or stronger will cause striking improvement early enough to improve the development of fruit that sets, but, with peaches at least, not early enough to cause more fruit to set. On very badly affected peach trees, freedom from leaf mottling continues later in summer after one spraying in spring than after one spraying in autumn.

On apricots, spring spraying seems as effective as autumn spraying, or more so.

Spraying in midsummer, after all dews or fogs have ceased in California, seems the least effective time, for peaches, walnuts, and citrus fruits at least, and probably for others, though grapes responded to spraying in June or July and young apricot trees to spraying in June. It seems probable that repeated moistening of the leaves by dew, fog, or light rains, may facilitate the intake of zinc.

Trees so badly affected that they bear very few leaves have not been made to bear normal leaves all summer as a result of one autumn and one spring spraying, but have made improvement in the first year and striking additional improvement in a second year of such treatment, suggesting that possibly two sprayings a year for 2 or 3 years may make very bad trees healthy enough for one autumn spraying a year to keep them free from little-leaf.

We have no results from spraying when the leaves are off, but the results that followed painting the whole tree with 2 pounds of zinc sulphate to 1 gallon of water suggest that spraying at that time might be effective. The cost of higher concentration should be partly offset by the smaller amount of spray required to cover a leafless tree. Strong winter sprays of zinc-lime to control little-leaf and leaf curl or Coryneum blight are being tried.

Spraying seems more effective on grapes than on other fruits except Citrus. Apparently one spraying a year, soon after growth starts, with zinc-lime 10–5–100, will be enough to keep grapevines healthy. And apparently zinc will penetrate the leaves and cause benefit when applied at any time in the summer.

Two experiments were done in January 1933 with spreading zinc sulphate, 2 pounds in 1 gallon of water, on all bark and fresh pruning wounds on grapevines. The new suckers bore large leaves, free from mottling throughout the following summer, and fruit clusters that were compact with normal berries, instead of the straggling clusters of very small berries borne on untreated little-leaf vines. However, the material killed the buds on spurs left, and only suckers were formed. Trials are being made with weaker solutions and with leaving, temporarily, an extra node on each spur to protect the others. This method would be much more convenient than spraying to most vineyardists.

Citrus fruit trees with little-leaf seem to make excellent response to spraying with zinc-lime 10–0–100, any time from early autumn to early spring. Zinc sulphate can be added to lime-sulphur without

injury to the trees, but no extensive study has been made concerning any possible reduction in effectiveness of lime sulphur as an insecticide. With citrus, the effect of one spraying has lasted more than a year. In fact, the benefit from a summer spray seems to be much greater in the second summer than in the summer of application. Adding lime to the zinc sulphate solution, unless lime-sulphur was included, seemed to reduce effectiveness.

So far, walnut trees with little-leaf, sprayed with zinc-lime in late summer or autumn, have not shown any response. Spraying in spring caused no striking benefit, but we cannot say there was not a little benefit. These results suggest that spraying with zinc compounds may not be as effective for walnuts as for pecans (3). Further studies are being made to see whether there is some season when spraying is beneficial and whether there is a cumulative effect of successive sprayings that will eventually prevent little-leaf.

Introducing Zinc Through Holes in the Tree

Zinc sulphate:—The method of boring holes about 1.5 inches deep with a ⅜-inch bit, 3 to 4 inches apart around the trunk or branch, filling these to within ½-inch of the surface with zinc sulphate, leaving none on the outer sapwood and bark, and plugging with grafting wax or "tree seal" has continued to give the most dependable results of any method of application, except spraying on Citrus and grapes. On deciduous trees, the beneficial results show earlier in spring than from any other method except autumn spraying, which shows slightly earlier. The benefit seems nearly always to last well through the second summer, but seldom longer.

We have had complete recovery in all parts of a tree to follow treatment in two holes, on opposite sides of a trunk about 16 inches in circumference, but we have had one branch on a tree fail to show benefit, apparently getting little or no zinc sulphate, when four holes equally distributed in a trunk about 20 inches in diameter were used. It seems that every 3 or 4 inches is about the right distance. Mr. M. H. Kimball, working in Los Angeles County, had uniformly early and striking response in walnut trees treated by this method, in a number of orchards where soil treatment did not get enough zinc to the buds of large trees to cause strong evidence of benefit by the end of the summer following. Similar results have followed treatment of apple trees in California and Washington and of apricot trees in California. However, we are still afraid that injurious effects may eventually follow the killing of so much sap wood (2). The method is very useful for experimental purposes.

When one branch is treated in this way, little-leaf is cured on all its branchlets above the holes, and small lateral branches as much as a foot below the holes may be benefited, but larger lateral branches below the holes, or even small laterals 2 feet or more below the holes, show no benefit. Thus one branch on a tree may be used as a check to compare with a treated branch.

Zinc dust:—In January 1933, at the suggestion of Mr. David Appleman, three Phillips Cling peach trees had finely powdered zinc

placed in holes 3 inches apart around the trunks. By May 15 these trees seemed to be showing striking benefit, though there was not strong evidence of benefit on April 15 when trees treated with zinc sulphate by this method were first observed to be showing benefit. On June 12, some of the holes were opened. Most of the zinc was still present, solidified into a firm mass.

Zinc oxide:—When it was found that powdered zinc seemed to cure little-leaf, zinc oxide was applied in the same way. Of course, trees treated toward midsummer could not show response in the same year unless they grew rather late. A few trees that were making some growth 2 or 3 months after treatment had healthy leaves on the very latest growth, while untreated trees that had been selected as comparable checks bore mottled leaves on that latest growth.

There is no evidence of injury to the tissue around the holes filled with zinc oxide. Callus grows readily and gum fills the holes on stone fruit trees. At holes filled with zinc sulphate, usually there is neither callus growth nor gum, owing to death of surrounding tissue.

Driving Zinc-Coated Nails or Zinc Triangles into the Tree

Soon after May 15, 1933, when powdered zinc was seen to have benefited three little-leaf trees, zinc-coated finishing nails and triangles of pure zinc, sides about 1 inch long, were driven into trunks or individual branches. Usually the nails were driven about six to an inch of trunk circumference, and the triangles about 1 to an inch. Any response to such treatment is slow, for the zinc is dissolved slowly, if at all. For example, wedges driven into a peach tree on June 25, 1933, and removed October 26 had not decreased in weight enough for measurement on scales accurate to 0.05 grams. Most of the trees or branches treated showed no response by the end of the growing season, though many of them certainly grew late enough to have shown a response to zinc sulphate placed in the trunk at that time. Nails and zinc triangles driven into branches of a number of orange trees on June 16, 1933, had not caused any improvement by December 12, though there had been several growth cycles. On the other hand, one stunted orange tree, with the top dying from little-leaf, treated June 15, one young peach tree, very bad with little-leaf, treated June 13, and one walnut tree, with little-leaf in all parts and apical parts dying, treated May 22, all with zinc-coated nails, improved, while adjacent trees grew worse; 3 peach tree branches and 2 young trees, into which zinc triangles were driven June 8–13, bore healthy leaves on the latest growth, while trees or branches selected as comparable at the time of treatment bore leaves most mottled and distorted on the latest growth. Because they remain in the tree, zinc-coated nails or zinc triangles should continue effective for several years, but we do not know what effect surrounding deposits of gum might have.

Corral Soils

Some have thought that, with Citrus at least, corral injury is exanthema, a disease cured by copper compounds. Because of their high fixing power for zinc, the corral soils concerning which we reported last year (2) required nearly 20 pounds of zinc sulphate to correct a tree. It could be argued that, with the very large quantities, the sulphate might have caused the benefit, or the zinc might have made enough copper available. In December 1932, therefore, four trees in one of these soils were treated with zinc sulphate through holes in the trunk. These trees were all strikingly benefited before May 18, 1933, and soon made growth enough to hide all little-leaf effect and give the appearance of normal trees in high vigor. The same response was shown by two very sick apricot trees in a small corral area in a heavy soil. Copper sulphate applied at the same time, February 3, 1933, and in the same way, through holes in the trunk, failed to cause the slightest improvement. Apricot trees showed the same response in another area in a soil that was a sheep corral many years ago. The recovery of all these corral trees following treatment through the trunk has been complete, in every way like the response of other little-leaf trees.

What Causes Little-Leaf?

Other substances than zinc through holes in the trees:—In an effort to determine whether or not little-leaf is merely a symptom of zinc deficiency, we have treated with many other substances. If any substance containing no zinc will cure the tree, and keep it healthy too long for the effect to be merely the result of making some zinc in the tree available, then little-leaf must be due to some other cause than deficiency of zinc for normal metabolism. Trees, usually three for each substance, were treated through holes 3 inches apart around the trunk in January and early February, 1933, with silver nitrate, nickel sulphate, cobaltous sulphate, stannic sulphate, stannic chloride, cadmium sulphate, mercurous chloride, mercuric chloride, ferrous citrate, ferrous sulphate, copper sulphate, manganous sulphate, and chromium sulphate, this last in only one tree. Early in the summer, trees treated with manganous sulphate and chromium sulphate looked somewhat better than the nearest checks, but that section of the orchard, unlike the section where trees were treated with the other substances, was one where even the checks did not show much leaf mottling in early summer; late in the summer there was a considerable amount of mottling even on trees treated with these two substances. We cannot be certain, therefore, that there was any response to manganese or chromium, and if there was a response it may not have been more than would have been caused if they had merely changed from insoluble to soluble form some of the zinc in parts of the tree. These elements are being tried in branches on a considerable number of trees this year.

All trees treated with any of the other compounds showed very bad little-leaf and mottling throughout the summer, although adjacent

trees treated with zinc sulphate at the same time by the same method, bore healthy leaves from April 15 to the end of the summer. Cadmium, nickel, and cobalt compounds caused some injury in the tops but not enough to prevent the appearance of a considerable amount of little-leaf and the growth of shoots bearing badly mottled leaves. The other substances caused no visible injury; the trunks have not been examined for the killed sapwood they probably contain.

It was assumed that silver and mercury compounds might be precipitated in the wood before reaching the buds. Therefore, on February 2, 1933, the bark of a Phillips Cling tree, especially the twigs, was painted with a silver nitrate solution, 4 ounces in 2 quarts of water, permitted to dry and painted again; a large branch of Phillips Cling peach tree was treated in the same way with mercurous chloride at the same strength. On both, a considerable amount of injury resulted, but some little-leaf tufts came out and shoots grew that bore badly mottled leaves. A branch on the same tree with the one having the mercurous chloride treatment was painted in the same way with a zinc sulphate solution and bore normal leaves from the beginning of the season.

We think that by very heavy soil treatment we have eliminated the possibility that calcium compounds, magnesium sulphate, aluminum sulphate, or any of the common fertilizer elements, may cure little-leaf.

Organic substances in the soil:—Of the organic substances tried (2), a ton of wheat straw to four trees, formaldehyde, pyrogallic acid, and toulene, have each failed to cause any benefit in the second year after application to a sandy soil in a Phillips Cling peach orchard. Additional trials in this orchard in January, 1933, were: pyridine, 10 pounds at one tree in water enough to make a 20 per cent solution, in a circular trench 2 feet from the trunk, and the same amount at another tree on the surface of all the soil within a radius of 8 feet from the trunk; pyroligneous acid, 20 pounds at one tree in enough water to make an 8 per cent solution, on the surface of the soil within a radius of 9 feet from the trunk, 10 pounds at another and 5 pounds at another, each dissolved in water to make an 8 per cent solution and each applied in a circular trench about 2 feet from the trunk; naphthalene flakes, 50 pounds at one tree, 30 pounds at another, and 20 at another, on the surface of the soil within a radius of 9 feet from the trunk. None of these caused any benefit in the first year. If they are ever beneficial, it will be by a slow improvement such as alfalfa causes.

Calcium compounds in the soil:—Calcium compounds seemed to precipitate the pigment associated with a toxin developed in artificial media by species of bacteria found in little-leaf-producing soils and in other soils. An effort was therefore made to get a large quantity of soluble calcium into the tree. A tree very badly affected with little-leaf was treated with 20, another with 40, and another with 80 pounds of calcium chloride; another with 20, another with 40, and another with 80 pounds of calcium nitrate; another with 20 pounds of calcium chloride and 20 pounds of calcium nitrate, and another with

TABLE I—Zinc Content of Shoot Leaves and Stems from Little-Leaf Trees and Trees with No Little-leaf Apical 6 to 8 Inches of Shoots, Bark and Wood Together

Kind	Source of Wood	No. of Samples	Zinc in p.p.m. Air Dry Weight		Leaves from the Same Shoots: Zinc in p.p.m. Air Dry Weight	
			Highest	Lowest	Highest	Lowest
Apple (Baldwin)	Little-leaf trees	2	5	5	10	4
	Orchards free from L. L.	3	25	24	30	6
Apple (Gravenstein)	Little-leaf trees	2	8	4	4	6
	Orchards free from L. L.	7	80	34	80	4
	Trees cured with $ZnSO_4$	2	46	36	16	12
Apple (Winesap)	No alfalfa, little-leaf	2	28	6	54	30
	Alfalfa, no little-leaf	2	24	16	40	25
Apple (Delicious)	Some L. L., young alfalfa	1	6	6	16	16
	No L. L., strong alfalfa	1	19	19	30	30
Walnut (Payne)	Little-leaf trees	4	17	8	22	11
	Orchards free from L. L.	5	34	24	30	16
Walnut (Grove)	Little-leaf tree	1	16	16	20	20
	Trees free from L. L.	1	26	26	26	26

Peach (Phillips Cling)	Little-leaf trees	5	12	5	15	6
	Orchards free from L. L.	6	32	18	43	6
	L. L. once but cured with $ZnSO_4$	5	50	14	24	12
	L. L. cured with $ZnSO_4$ but returning	2	11	10	14	7
	L. L. in corral area	1	9	9	6	6
	Healthy tree near but outside the corral area	2	16	11	14	11
Peach (Elberta)	Little-leaf tree	1	10	10	14	14
	Trees free from L. L.	3	36	18	30	15
Apricot (Blenheim)	Little-leaf trees	4	9	7	30	24
	Trees free from L. L.	3	25	12	27	19
	Trees cured of L. L. with $ZnSO_4$	5	34	11	31	24
Orange (Navel)	Bad little-leaf tree	2	8	6	10	9
	Trees nearly free from L. L.	2	16	12	13	10
Orange (Valencia)	Bad little-leaf trees	1	11	11	12	12
	Trees not very bad with L. L.	1	9	9	9	9

40 pounds of calcium chloride and 40 pounds of calcium nitrate, all in circular trenches about 2 feet from the trunks. All trees continued very badly affected with little-leaf, as bad as in the preceding year or worse. In former years, as much as 100 pounds of calcium sulphate had failed to correct a tree. It seems certain that large quantities of calcium cannot cure little-leaf in the way that zinc does. None of the trees receiving calcium nitrate alone was injured by the treatment. All strengths of calcium chloride alone, and 40 pounds of calcium chloride combined with 40 pounds of calcium nitrate, caused a considerable amount of leaf injury.

Analyses for zinc in shoots:—Samples of shoots and of leaves were taken from trees with little-leaf in soil and localities where little-leaf is bad, also samples from healthy trees, some in soils and localities where trees are free from little-leaf and some in orchards where trees are free from little-leaf but in localities where other orchards show much little-leaf. It was thought that if in sections like those receiving cold winds from the Pacific Ocean, or in the northeastern part of the United States, where little-leaf is not seen, zinc content in the tissue should be no greater than zinc content in little-leaf trees, the conclusion might be justified that little-leaf is not caused by a deficiency of zinc for normal metabolism.

The analyses were made by Mr. Hibbard, who will publish elsewhere the modification in standard methods he found necessary to obtain reasonably trustworthy results when the zinc content is only 3 to about 80 p. p m.

The material taken was, in so far as possible, the apical 6 to 8 inches of shoots on the periphery of the tree. The leaves were in all cases taken from the shoots that were analyzed. Shoots were analyzed without separation of bark and wood. Samples were taken in September and October, 1933. No column for averages is included in the table because not enough samples were used to make differences significant, with the rather large analytical error and the probable variation in zinc content of tissue from similar trees. The highest and lowest readings are shown in Table I.

The results with leaves, especially apple leaves, have very little meaning. The lead applied in spraying makes it very difficult to determine zinc accurately. But even peach leaves never sprayed with arsenate of lead, and from districts where little-leaf has never been seen, seemed to have as little as 6 p. p. m. of zinc. If we had taken only leaves for analysis we might have concluded that little-leaf is not associated with a low zinc content. However, Table I suggests that shoots of little-leaf trees tend to be lower in zinc content than shoots from orchards where there is no little-leaf. We do not present this table as convincing evidence that little-leaf results from a supply of zinc too low for normal metabolism. Many more analyses would be required, especially analyses of the different parts of the tree, and at different periods, to see whether the low zinc content of little-leaf shoots may not be due to precipitation of zinc in the lower part of the tree by some substance that may cause little-leaf, or whether the higher zinc content of healthy shoots may not be in part the result of

greater absorbing power of a more active root system. To separate cause and effect is not yet possible. On the other hand, these data certainly do not support the view we have held (2): that zinc in some way may prevent injury from a postulated toxic substance produced by soil organisms and absorbed by the tree. Evidence obtained during the past year does show that certain organisms isolated from little-leaf soils and grown in artificial media may produce substances highly toxic to young peach, apple, and Citrus trees, but proof is lacking that similar substances are produced under field conditions.

Failure of trees grown in tanks of little-leaf soil to show little-leaf:—Last year we presented, as argument against the view that little-leaf is a symptom of deficiency of zinc for normal metabolism, the fact that the soil in which trees are showing bad little-leaf is placed in containers and trees planted in it, such trees have not shown little-leaf in Berkeley. We were inclined to attribute this to a temperature influence. However, analyses show that this may result from a better zinc supply. The shoots of these trees contain 36 to more than 300 p. p. m. of zinc, the lowest being more than has been found necessary to keep a tree from little-leaf in the orchard. This abundant zinc supply seems to come from the galvanized pipe and from zinc in rubber of the hose used in irrigation.

Fluctuation in severity of little-leaf and recovery without treatment:—Last year (2) we said that in some districts trees may be very bad with little-leaf in one year but, without any change in treatment of soil or trees, may recover and be free from it for a number of years, then be bad again. We thought these changes might possibly be correlated with summer temperature. However, the trees that have shown this fluctuation most strikingly do not respond to application of zinc, and the tufts of small leaves which we considered to be the same as true little-leaf were very different from little-leaf rosettes when examined as they were opening. In other words, the trouble we were observing in parts of that district was not little-leaf; on the other hand, it is true that in other districts the severity of little-leaf does sometimes fluctuate from season to season.

Summary as to cause of little-leaf:—By injection in the tree, or by very heavy soil treatments, compounds of 14 cations have been tested as cures for little-leaf. Six organic substances have been added to the soil to see whether they would influence the soil flora favorably to the development of normal trees and the curing of little-leaf. Weak solutions of pyridine and of guaiacol were injected into trees to see whether they would correct a possible toxic condition resulting from an unfavorable soil flora. With the very doubtful exception of manganese and chromium compounds, none has yet caused any observable improvement in little-leaf trees.

Analysis of samples from 11 districts where trees do not show little-leaf, eight in California and one each in Indiana, Maryland, and New York, have failed to show one in which zinc content of shoots is as low as that in shoots with little-leaf, though a number of leaf samples from such districts were as low in zinc content as leaves from little-leaf trees.

Trees that remained healthy when grown in tanks of a soil that produces little-leaf in the orchard may have done so because they were watered through pipes and hose that gave up zinc to the water.

The apple trees that seemed to recover from little-leaf without any change in tree or soil treatment have, not little-leaf, but some other disease.

Practically all our observations during this year are in harmony with the view that little-leaf is a symptom of deficiency of zinc for normal metabolism. Yet, because of the suddenness with which a healthy, vigorous tree may begin to die from little-leaf, because some trees have recovered and others improved without any conceivable improvement in the zinc supply, and because of the very general susceptibility of large woody perennials and the apparently general freedom of annual plants, grown in the same soils, from little-leaf, we are not convinced that it is due merely to a zinc deficiency. We believe that the cause of the disease remains an open question requiring further evidence.

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Effectiveness and Safety of Fungicide-Arsenical Spray Combinations on Apple in the Champlain Valley of New York

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THIS is the second report on spraying experiments in the Champlain Valley. Data were presented last year (1) to show that in a year only moderately favorable for the development of apple scab, both lime-sulfur and Koppers flotation sulfur, each used throughout the season, gave excellent control of the disease. Lime-sulfur was slightly and significantly superior in scab control, but caused appreciable foliage injury in two of the five orchards where the experiments were conducted. A blended paste form of Koppers flotation sulfur gave results equal to those obtained with a dry wettable form.

Scope and Methods of 1933 Investigations

In 1933, cooperative experiments similar to those of 1932 were conducted in six McIntosh orchards in the northern part of the Champlain Valley. The orchards are designated as D, E, F, G, H, and I, respectively. There were from 16 to 60 trees per plot and one plot of a treatment per orchard. In most orchards, seven applications were made, two before and five after bloom. Such exceptions to this as occurred seem not to affect the trend of the results. Except where specified, treatments were carried throughout the season. There were, in general, four count trees per plot, so chosen that individual pairings of count trees of contrasting treatments could be made and the data analyzed by Student's method.

In addition to these cooperative tests, more extensive series of plots were laid out in three other McIntosh orchards to test fungicide-arsenical combinations, different brands of calcium arsenate, and the effectiveness of so-called "correctives" to arsenical and lime-sulfur injury.

In one of these, designated as orchard A, the trees were in high vigor, about 20 years of age, and spaced 40 by 40 feet. This block was divided into 20, one-row plots, with 8 to 12 trees per plot. There were 10 treatments, each on two plots. The treatments by number, occurred in the following order: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 9, 10, 8, 7, 6, 5, 4, 3, 2, 1. The writer and assistants did the spraying.

In the second orchard designated as B, the trees were of medium vigor about 15 years of age and spaced 33 x 33 feet. There were seven plots each consisting of a single row of about 24 trees and a different treatment was given on each plot. Materials were measured out by the writer and assistants, but applied by the grower.

In the third orchard, designated as C, the trees were in very low vigor, about 20 years of age, in rows about 33 feet apart. On some of the trees, the average terminal growth was less than 2 inches. There were 11 treatments, each on a single row. Spraying was done by the experimenters.

In all experiments, except when indicated, the following concentrations of materials were used: liquid lime-sulfur, 1 to 40 by volume; Koppers dry wettable flotation sulfur, 8 pounds per 100 gallons up to and including the first cover spray and 5 pounds per 100 gallons thereafter; nickel flotation sulfur paste,[1] same concentration on a dry basis; all arsenicals, 2 pounds per 100 gallons.

In nearly all cases, all apples on the count trees were examined and all blemishes that could be identified were counted, no matter how small. Count trees were chosen as in the cooperative experiments. All orchards in the experiments had moderate to heavy crops, except orchard I which had a light crop and orchard C, which had an extremely light one. The untreated check trees unfortunately received considerable amounts of drifting spray especially early in the season.

In orchards A and B, of high and medium vigor respectively, the data are combined with those in the cooperative tests when treatments were comparable. In the extremely low vigor orchard, C, there was less than a 10 per cent crop, so the data are not so combined. In addition to the experimental layouts just described, some spraying experiments for apple maggot and some arsenical injury experiments on young non-bearing trees will be summarized briefly.

Weather

The monthly precipitation during the growing season with deviation from the normal was as follows: April, 3.03 (+1.02); May, 2.84 (+0.40); June, 1.86 (—1.05); July, 0.99 (—2.34); August, 3.98 (+1.38); September, 1.90 (—1.31). A plus deviation means that the precipitation was above normal. With summer temperatures above normal, the deficiencies in rainfall during June and July resulted in acute drouth which was only partially relieved by the few heavy rains of August and September. The most important primary scab infection period of the year occurred during bloom. A rain period at delayed dormant stage resulted in infections varying from very slight to moderate in the different orchards. Such other spring infection periods as occurred were unimportant except possibly in orchard B. On the whole, the season was only moderately favorable for the development of apple scab, being about average for the region. August and September rains resulted in some late spread to the fruits. Temperatures were above normal for the region throughout the spring and summer.

Results

1. *Effectiveness of the program as a whole:*—This may be judged by the following figures which represent the average for all treatments in orchards A, B, D, E, F, G, H, and I. Blemishes preventable by spraying or caused by spraying are included. About half of the plots received lime-sulfur throughout the season, and half of them either Koppers dry wettable or a nickel paste form of flotation sulfur. In most cases, lead arsenate was used before bloom and calcium arsenate

[1]Obtained from Co-operative G. L. F. Mills, Inc.

after, though some plots received calcium arsenate throughout the season and a few, lead arsenate throughout.

As an average 74.6 per cent of the fruits were blemished on unsprayed check trees, compared with 14 per cent on sprayed trees. The program was very effective in the control of apple scab, there being 51.8 per cent of the fruits affected on the unsprayed trees in comparison with 1.6 per cent on the sprayed trees. The program was less effective against codling moth, there being 14.6 per cent of the fruits affected on unsprayed trees in comparison with 6.8 per cent on sprayed trees. The percentge of fruits with deep worm holes was reduced from 12.7 on the checks to 4.3 per cent on the treated plots. It was not very effective against green fruit worms and leaf-rollers, the treatments having reduced the injury from 5.3 to 3.0 per cent, mostly due to green fruit worms. Lead arsenate plots had slightly less of this injury than calcium arsenate plots. Plum curculio injury was reduced from 1.5 to 0.5 per cent and late leaf-roller (a species causing injury chiefly around the stem end of the fruit at harvest time) from 1.1 to 0.5 per cent. Cheek scald was increased by spraying from 0.3 to 0.8 per cent and calyx burn (arsenical injury) from 0 to 0.8 per cent. Calyx burn is a serious injury since it is difficult to sort out and sometimes leads to a soft rot of the fruit in storage. It did not occur in the lead arsenate plots.

2. *Effectiveness of fungicides in apple scab control:*—The data on scab control are based on the examination of about 300,000 fruits, constituting the crops of 155 count trees. In 1932 (1) it was pointed out that the average percentage of fruits scabby on plots sprayed with Koppers dry wettable flotation sulfur was 1.0 per cent in comparison with 0.2 per cent for lime-sulfur 1–40. In 1933, the corresponding figure for Koppers flotation sulfur powder was 1.0 per cent and for lime-sulfur 1–40, 0.7 per cent. Each of these 1933 figures is the average for 26 count trees distributed among six orchards. There is no significant difference between lime-sulfur and Koppers dry wettable flotation sulfur in effectiveness against scab this particular year. The unsprayed checks in these six orchards averaged 47 per cent scab.

In orchard A, the addition of 6 pounds of Chazy hydrated lime per 100 gallons did not influence the degree of control of scab, either in lime-sulfur-calcium arsenate or in flotation sulfur-calcium arsenate plots, the amount of scab being below 1 per cent in all plots. The three check trees which received only accidentally drifting spray in this orchard had 45, 50, and 59 per cent scab respectively. Similar results were secured in orchards B and C, where the scab infection was somewhat higher. There was no difference in scab control correlated with the use of lead arsenate or calcium arsenate either with lime-sulfur or with flotation sulfur, either with or without excess lime.

The Koppers dry wettable flotation sulfur is a powder derived from a blend of the flotation sulfurs produced in a number of different gas plants using somewhat different processes. In addition to this blended dry wettable product, a paste produced by a single gas plant using the so-called nickel process was included in the tests. In each

of four orchards, a plot of nickel flotation sulfur paste was included for comparison with the Koppers dry wettable flotation sulfur and the lime-sulfur. In these four orchards (14 count trees for each treatment), the average amount of scab was 0.4 per cent for lime-sulfur, 0.6 per cent for Koppers dry wettable flotation sulfur, and 0.6 per cent for nickel flotation sulfur. The average for the unsprayed checks in these orchards was 44.1 per cent.

There were four count trees receiving 1–40, and four receiving 1–50 lime-sulfur, in orchard A. The average scab for each of these concentrations was 0.3 per cent, the range being from 0.1 to 0.6 per cent for 1–40, and from 0.1 to 0.5 per cent for 1–50.

The addition of zinc sulfate-hydrated lime mixtures at concentrations from 2–2–50 to 4–4–50 to lime sulfur-calcium arsenate and to flotation sulfur-calcium arsenate combinations in orchards B and C had no clear-cut influence on prevalence of apple scab. (See discussion of spray injury).

The addition of ferrous sulfate at the rate of 4 pounds for each gallon of lime-sulfur to lime-sulfur-calcium arsenate combinations almost completely eliminated the effectiveness of the mixture in "burning out" scab lesions already visible on the foliage. This combination could well be classed with the wettable sulfurs from this point of view. It is said that in Nova Scotia, increasing the concentration of calcium arsenate to 5 pounds per 100 gallons increases the effectiveness of the combination in "burning out" scab.

In orchard B the unsprayed check tree showed 99.6 per cent of the fruits with scab, and some of the spray applications were not well timed. The end trees on five plots receiving different wettable sulfur sprays throughout the year were dusted with sulfur during bloom. The dusting was timely with reference to the principal scab infection period of the year which came during the blooming period. The percentage of fruits with scab was determined for a tree receiving the special dust during bloom, and for a similar, adjacent tree receiving only the regular sprays. The percentage of fruits with scab for the dusted and the non-dusted tree in each plot is respectively, 7.9 and 19.4 per cent, 3.7 and 12.0 per cent, 4.4 and 10.5 per cent, 4.6 and 6.4 per cent, 2.1 and 3.0 per cent, or an average of 4.5 for those with the special dusting against 10.2 per cent for those with the regular treatments only. No noticeable reduction in yield occurred, the conditions having been moderately favorable for pollination.

In another orchard receiving a lime-sulfur schedule of seven sprays, not very well timed, one McIntosh tree received four dustings with sulfur and one spray with Koppers flotation sulfur during bloom. The pink spray was 4 days too early. Previous to this dusting, there were 2 excellent days for pollination, and the block contained a mixture of varieties. The dusted McIntosh tree had 1.5 per cent scab, compared with 5.4 per cent scab for a comparable tree not dusted. The set of fruit even on the dusted McIntosh tree was excessively heavy, breaking down a large branch. In the light of previous work (2) no reduction in yield would have been anticipated under the conditions of these experiments.

3. *Injury to foliage and fruits caused by fungicides:*—In the report for 1932 (1) it was pointed out that in two orchards lime-sulfur plots showed severe foliage injury while corresponding flotation sulfur plots did not. In one of these orchards the treatments were continued in 1933 on the same plots. In 1932 yield of all trees was heavy, the spraying was heavy and the tree vigor below average. The 1933 bloom of the flotation sulfur plot was estimated to be about five times that of the lime-sulfur plot. The 1933 yield of a 10 tree segment of the flotation sulfur plot was 64 bushels, compared with 23 bushels for the corresponding lime-sulfur plot. This 1933 reduction in yield was a result of reduction in fruit bud formation the preceding year. No clear-cut reduction in fruit bud formation or in 1933 yield resulted from the 1932 lime-sulfur treatments in the other four orchards.

In the 1933 treatments the lime-sulfur caused a small to moderate amount of visible foliage injury, especially in the applications before bloom and at petal-fall. Flotation sulfur plots were practically free from this injury. Only a small amount of sulfur injury on the cheeks of the fruits occurred in the plots (average of 0.8 per cent). There was no significant difference between the materials on this point.

4. *Effectiveness of different arsenicals in control of maggot and codling moth:*—One small block of old Snow trees has received lime-sulfur and lead arsenate, and a comparable block 400 feet distant, lime-sulfur and Niagara brand calcium arsenate in all spring and summer sprays for the past 4 years. No correctives have been used. The maggot infestation in each approached 100 per cent before the start of the experiment. The infestation has been determined by a count of all of the fruits on two representative trees per plot each year, entomologists of the New York (Geneva) Agricultural Experiment Station cooperating in making the maggot sprays and taking the data. There has been no significant difference between lead arsenate and calcium arsenate in maggot control.

In 1933, two comparable block of old trees about 800 feet apart were chosen for maggot control experiments, all varieties in both orchards having been heavily infested during previous years. One block received two thorough applications in July of calcium arsenate and flotation sulfur paste while the other received similar treatments with manganese arsenate (Manganar) and flotation sulfur paste. In the calcium arsenate block, the maggot infestation was reduced to below 2 per cent in the varieties Snow, McIntosh, and Spy. In the Manganar block, the infestations on two Snow trees were respectively 4.1 and 3.5 per cent. Drops and picked fruits were counted. These reductions in infestation are at least as satisfactory as we usually have gotten the first year from spraying with lead arsenate in tests extending over the past 6 years.

As to codling moth control, we had no good comparisons between lead arsenate and calcium arsenate in heavily infested orchards. In orchard A, where the writer and assistants did the spraying, there were five count trees averaging about 3,500 fruits per tree in plots receiving four cover sprays with lead arsenate and five comparable

count trees in similar plots sprayed with calcium arsenate. Both arsenicals were used at the rate of 2 pounds per 100 gallons in the first cover spray and 1 pound per 100 gallons in the three later ones. With lead arsenate there were 14 stings and 3 deep wormholes per 1,000 fruits, as compared with 9 stings and 4 deep wormholes per 1,000 fruits for calcium arsenate. The three check trees receiving only drifting spray, averaged 14 stings and 26 deep wormholes per 1,000 fruits.

In orchard C which had an extremely light crop and a moderate codling moth population, an abbreviated program of summer spraying was followed. There were 69 stings and 31 deep wormholes per 1,000 fruits with lead arsenate compared with 52 stings and 46 deep wormholes with calcium arsenate. The ratio of wormholes to stings indicates somewhat poorer control with calcium arsenate than with lead arsenate. With magnesium arsenate, the control was poorer than with calcium arsenate. The two unsprayed check trees in this orchard had 2 stings and 329 deep wormholes per 1,000 fruits. The data from another experiment indicate that manganese arsenate (Manganar) is between calcium arsenate and lead arsenate in effectiveness against codling moth.

Among eight orchards receiving similar programs of summer spraying with calcium arsenate, the percentage of attempted codling moth entrances that were successful varied from 19 to 75 per cent. Entrances were considered successful if the worm penetrated ¼ inch or deeper. Seven of these orchards were sprayed by the growers. This is one measure of the effectiveness of the current season's spraying operations against this pest. The percentage of fruits injured by codling moth in these orchards varied from 1 to 22 per cent. This percentage is influenced by the current year's spraying, by previous years' spraying, and by natural conditions of the orchard.

5. *Injury to foliage and fruit caused by arsenicals, and the effectiveness of certain so-called correctives to arsenical injury:*—These results are presented with a realization that different ones have been obtained in other regions, and doubtless would be obtained here with other varieties and different weather conditions.

Nearly all commercial orchards in the Champlain Valley of New York received calcium arsenate at the rate of 2 pounds per 100 gallons in place of lead arsenate in the cover sprays. "Sherwin Williams" was the brand most commonly used. A few used calcium arsenate as the only arsenical in both pre-bloom and cover sprays. In about half of the summer applications, calcium arsenate was combined with lime-sulfur, and in about half with nickel flotation sulfur. In very few cases was lime or any other corrective added to the mixture.

In general, there was little foliage injury, although in August and September moderate to severe scorching of margins of spur leaves appeared in a few orchards. In experimental plots receiving flotation sulfur and calcium arsenate at the rate of 2 pounds per 100 gallons, this injury was almost entirely eliminated when hydrated lime was added at the rate of 3 pounds for each pound of calcium arsenate. In

plots receiving lime-sulfur and calcium arsenate without correctives, this late-season foliage injury was less severe than in those receiving flotation sulfur and calcium arsenate. The lime-sulfur evidently served as a partial corrective to the arsenical injury. The addition of hydrated lime to the lime-sulfur-calcium arsenate combination did not materially reduce the injury. It is probable that in this case much if not all of the injury was due to lime-sulfur. In orchard C, which is in extremely low vigor, there was some yellowing and defoliation in all plots, especially where lime-sulfur was used.

The use of zinc sulfate and hydrated lime at concentrations of 2–2–50, 3–3–50, 4–4–50 in combination with calcium arsenate and lime-sulfur and with calcium arsenate and flotation sulfur seemed to reduce foliage injury slightly. However, there was a considerable amount of russeting of fruit such as commonly results from Bordeaux mixture. In addition, the zinc sulfate mixture did not stay in suspension well in the spray tank.

The addition of ferrous sulfate at the rate of 4 pounds for each gallon of lime-sulfur in all applications up to July 1, materially reduced foliage injury, as compared with that on plots receiving just 2 gallons of lime-sulfur and 2 pounds of calcium arsenate per 100 gallons.

Arsenical injury experiments were conducted on about 200 3-year-old vigorous McIntosh trees and on branch units of a few large McIntosh trees. The arsenicals were applied with hand sprayers, alone and in combination with wettable sulfurs and so-called correctives to arsenical injury. At first, the arsenicals were used at such concentrations at 2, 3, 6, and 8 pounds, respectively, per 100 gallons. Since injury was slow to develop and was mild, a series of tests was inaugurated using lead arsenate, manganese arsenate (Manganar) and different brands of calcium arsenate at the rate of 25 pounds per 100 gallons, alone and in combination with wettable sulfurs, but without correctives. Two applications were made near the end of August, with two trees for each combination of materials. A few terminals of the trees were still growing slightly.

In these high-concentration arsenical experiments, no injury resulted from lead arsenate (Sherwin-Williams brand), the only brand tested. Only slight injury resulted from manganese arsenate (Manganar). Calcium arsenate injury appeared about 3 weeks from the first application, and developed slowly until frost. The injury was consistently a little more severe with the G.L.F. brand of calcium arsenate than with the Niagara, Sherwin-Williams, and Grasselli brands which behaved about alike, causing only moderate injury. The Bowker Chemical Company's "Calrox" did not cause injury until about 2 weeks later than the other brands, but the ultimate injury was at least as severe as that caused by any other brand tested. No defoliation occurred on any of the trees. The injury was chiefly a killing of leaf margins and of leaf areas previously injured by scab, insects or mechanical agencies.

6. *Arsenic and lead residue on fruit at harvest:*—During the 3½ months preceding harvest, there was only 7.73 inches of rainfall,

compared with a normal of 10.44 inches. The 1933 federal and state tolerance on arsenic was .01 grains of arsenic trioxide per pound of fruit and .02 grains of lead. The results of spray residue studies are summarized in the following paragraph.

Where lead arsenate was used at the rate of 2 pounds per 100 gallons in four cover sprays in experimental orchards, the residue was 150 to 200 per cent of the tolerance both on arsenic and on lead. Where calcium arsenate was used at the same rate and on the same schedule, the residue was from 30 to 100 per cent of the arsenic tolerance. Where lead arsenate was used at the rate of 2 pounds per 100 gallons in the first cover spray, then 1 pound per 100 gallons in the last three cover sprays, the residue was just within the tolerance. Where lead arsenate was used in two cover sprays, then three applications of dust containing 10 per cent of calcium arsenate were substituted for the last two cover sprays, the arsenic residue was 90 per cent of the tolerance and the lead residue low.

In all cases, the fruits showing the most residue were taken as samples, as is the custom with inspectors. I am indebted to Mr. G. W. Pearce of the New York Agricultural Experiment Station at Geneva and to the New York State Department of Agriculture and Markets at Albany for analyses. In the Albany analyses, official samples were taken by department inspectors.

The plots had all received what would be considered thorough commercial spraying in the region, the opeartor usually working from the spray tank only. A well-grown 20-year tree with a spread of 25 feet received about 14 gallons of material in the summer applcations. This is, of course, much less than is customary in some regions where codling moth is very serious.

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Some Effects of Special Practices Influencing the Nutritional Balance on Yield, Texture, and Time of Maturity of Grapefruit

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THE production of grapefruit has become an important industry in Arizona. In the arid southwest, the trees are grown under different and perhaps more severe environment than obtained in their original habitat.

In Arizona, extreme summer temperatures combined with low relative humidity have been thought to be responsible for the production of fruit having a coarser and thicker rind than fruit of the same variety produced in more humid climates. The fact that on mature trees, the finer textured fruit is produced within the sheltered portion of the tree, whereas outer and exposed fruit is more coarse, is given as evidence supporting this theory. These same climatic features have also been suggested as the cause of the rather heavy shedding of young fruits which tends to limit yields.

It is realized that moisture relationships may have an important bearing on yields and quality of fruit. The transpirational demand for water may, on occasion, be greater than can be supplied to the leaves by the absorbing and conducting system of the tree, even tho ample soil moisture is available. In the early summer, while the fruit is small, the tree apparently responds to such a stress by the development of abscission layers at the calyx and the shedding of small fruits. In the latter part of the summer, shedding of fruit does not result—instead it loses turgor and becomes soft—suggesting that moisture is withdrawn to be transpired by adjacent foliage.

As external environmental features cannot be greatly modified, the question of whether or not the various phases of fruiting might not be influenced by the growth condition and nutrition of the tree becomes paramount, as these latter are perhaps susceptible to cultural treatments. It was therefore thought desirable to consider fruiting in relation to some physiological conditions of the tree as induced by certain cultural and other practices.

This was attempted with experimental trees on the Yuma Mesa Citrus Station of the University of Arizona by: (a) Applying 5 pounds of ammonium sulfate per tree just after each irrigation thruout the growing season (a total of 55 pounds per tree was applied), (b) by girdling and regirdling at intervals for varying periods of the growing season, (c) by varying widely the harvest date of the previous year's crop and (d) by shading entire trees to the extent of reducing the light intensity somewhat more than one-half. Girdles completely encircled the tree trunks the width of a knife blade, barely penetrating thru the bark, and were renewed at 2-week intervals, on some trees, thruout the growing season.

Samples of shoots were collected from trees of the different treatments at intervals thruout the growing season. These were stored in a solution of formalin, alcohol and acetic acid. Later free hand cross sections were made at the tip and base for microscopical study. Leaf samples for determinations of the osmotic value of the expressed sap were collected during the season of fruit shedding. From one tree of each treatment and from a check tree, 12 fruits were picked at approximately weekly intervals from October to early December. On these, data were taken on size and weight of fruit, color, texture and thickness of the rind, texture of the flesh, amount of juice, per cent soluble solids (Brix) and acid, and sugar-acid ratio. Corresponding trees were harvested at one time in late November and total yield recorded.

Trees continuously shaded thru 1932 and 1933 failed to blossom in the spring of 1933. These trees produced long, slender, almost vine-like shoots. Leaves were extremely large, very thin and of a dark green color. The osmotic value of sap from the leaves was but 78 per cent of that of leaves from exposed trees. Shoots in the early summer were devoid of starch except for a small amount in the endodermis whereas those from check trees carried abundant starch well distributed thruout the various tissues. The xylem was narrow with few parenchyma cells. The xylem fibers had thin walls and large lumens. Pith cells were large and without secondary wall thickenings.

Trees which were still carrying the 1932 crop at blossom time in 1933 produced fewer and smaller blossoms than check trees or than trees harvested early. Girdling was not initiated until after blossoming.

Evidence that any treatments influenced shedding of young fruits is not pronounced. The ratio of the number of fruits shed from April to July to the number matured was relatively higher for heavily nitrated or pruned trees or for those from which the previous crop was harvested early than for check or girdled trees. The drop on trees that carried the 1932 crop late into 1933 was relatively small which may have been related to the light blossoming of these trees. Wide differences in anatomy or starch content of shoots from the early and late pick trees were not apparent in May and June following blossoming.

With the 1933 season generally characterized by but slight change in fruit maturity (total soluble solids-acid ratio) from October to December, rather significant differences in factors constituting maturity were found in fruits from trees receiving the different treatments.

Girdled trees tended to mature fruit somewhat earlier than similar non-girdled ones. The development of color was definitely earlier. The rind was smoother in texture and thinner than that of fruit from check trees. The percentage of total soluble solids in the juice was relatively high and the acid content lower than with fruits from most other treatments. The trees repeatedly girdled thruout the growing season made no fall growth. Leaves became yellow, thick and coarse

as the summer advanced. The internal anatomy and starch content of the shoots did not appear to reflect quite the wide difference observed in the external appearance of the tree. In the shoots, the xylem was moderately wide with relatively many parenchyma cells in the outer xylem. Xylem fibers had thick walls and small lumens. Most pith cells had secondary wall thickenings. Starch was abundant in all tissues.

The heavily nitrated trees produced fruit in which more acid developed than in the checks and in which the acid content remained high thru the early harvest season. While the total soluble solids (sugar) was also high, the ratio of sugar to acid was low and maturity delayed. Rind texture was not noticeably affected by this treatment but the development of color was definitely retarded. These trees made considerable fall growth. Leaves were moderately large and of a deep green color. The trees were in striking contrast to those girdled repeatedly thru the season. Wide differences in anatomical features are not revealed in studies to date. Shoots from these trees had a wide xylem the outer part of which contained relatively many parenchyma cells and starch was present in all tissue but apparently not so abundant as in the girdled trees.

The size of fruit was not consistent with treatments. Repeated girdling tended to make for larger fruit, particularly when done in late summer. Excess nitrogen had the same effect. The largest fruit was produced on trees from which the previous year's crop had been harvested late. These trees bore the fewest fruit, however, which probably accounts for the increased size.

Total yields were also variously affected. The shaded trees, as previously indicated, produced no blossoms or fruit. The yield of trees which carried the 1932 crop until May, 1933, was 35 per cent less than on similar trees harvested in November, 1932. Trees girdled in the spring and those regirdled at intervals until fall yielded heavier than check trees on the basis of their previous production records. Yields were reduced slightly on pruned trees, and on the heavily nitrated trees. The greatest increase in yield over the previous season's production occurred on trees harvested in November, 1932; the greatest reduction was with those which carried the 1932 crop until May, 1933.

A point of especial importance suggested in this study is the effect of nitrogen on the acid content of the fruit. In citrus fruit, quality and maturity depend not alone on the total accumulation of carbohydrates and related compounds in the fruit but chiefly upon the accumulation of sugars in relation to organic acids. If this relationship is influenced by the presence of nitrogen, a means of adjusting maturity within limits may be possible when more is learned of the utilization and rôle of nitrogen in citrus trees.

Results thus far obtained are believed to indicate that some phases of fruiting of grapefruit may be related to growth and nutritional factors of the tree as influenced by the various treatments. A continuation of the studies will include efforts to more accurately measure physiological and chemical processes associated with fruiting.

Seasonal Variation in Oxidation-Reduction Potential of Some Orchard Soils

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IT has been shown previously (2) that definite relationship exists between tree yields and certain properties of the soil profile. It was found that any determination or method which measured either directly or indirectly the drainage properties of the soil was of considerable value in appraising a given soil for orchard purposes. More recently it has been found that the oxidation-reduction potential of a soil may be a valuable means of determining its suitability for orchard purposes (1). One of the factors involved in using such a measure of orchard site selection is the seasonal nature of the redox potential. The present paper is concerned with this angle of the problem.

In any soil there exists an inverse relationship between the air and water content. During the spring months in most of our soils the amount of water greatly exceeds the air content. Under conditions where the oxygen supply becomes limiting, the microorganisms of the soil are forced to draw upon the oxygen reserve in order to carry on their biological activities. As a result, some of the more abundant constituents of the soil, such as iron, are reduced to a lower valence form. The following table illustrates the changes from an oxidized to a reduced state that some of the more important soil constituents may undergo as a result of water logging (1):

TABLE I—CHANGES IN SOIL CONSTITUENTS DUE TO WATER LOGGING

Element	Normal Form in Well Oxidized Soil	Reduced Form Found in Water Logged Soils
Carbon	CO_2	CH_4
Carbon	—	Complex aldehydes, etc.
Nitrogen	NO_3+	N_2 and NH_3
Sulfur	SO_4++	H_2S
Iron	Fe +++(Ferric)	Fe++(Ferous)
Manganese	Mn+++(Manganic)	Mn++(Manganous)

As the ground water level recedes the oxygen supply naturally increases and the above changes take place in the reverse order; that is, the reduced forms gradually become oxidized. The degree or extent of these oxidation-reduction changes in the soil can readily be ascertained by a measurement of the oxidation-reduction or redox potential.

A satisfactory method (and the one used in this investigation) for measuring the redox potential of soils has been described by Bradfield, Batjer, and Oskamp (1). Lack of space prevents submitting the full details of the procedure but briefly it is as follows: Approximately 10 gms of soil are placed in a small sampling bottle in which are added 10 cc of N/10 sulfuric acid. The bottle is stoppered,

shaken until the soil becomes thoroughly dispersed, and then allowed to stand over night. The potential is measured by introducing two blank platinum electrodes into the soil suspension; this is in turn connected by means of a KCl agar bridge to a saturated calomel half cell, and the E.M.F. is measured with a potentiometer. Alternate readings are taken with the two electrodes at intervals of 1 minute each until a stable potential of the same value is obtained with both electrodes. When the potential is measured against a standard calomel half cell the E.M.F. obtained is expressed in terms of the normal hydrogen electrode by the addition of .250 volts. The value thus obtained is designated as the E_H or redox potential. Since the E_H is an inverse linear function of the pH value (provided the ratio of oxidant to reductant remains the same) a pH determination was made immediately after the redox measurement. All values were then corrected to a constant pH. On the H-ion scale, pH 3.0 was chosen because most of the measurements were made at or near this hydrogen-ion concentration. A change of .080 volts per pH unit was used in making these corrections instead of the theoretical value of .060 because experimental work done on a number of different soils shows this as the most probable factor (1).

Experimental

On April 21, 1933, the redox potential on the B_1 horizon (at a depth of 18 inches) was measured under high and low yielding trees in the Pomology Orchard at Ithaca and in a commercial orchard at Hall. Samples were taken and the measurements were repeated at irregular intervals throughout the 1933 season, the last determination being made on December 16.

The soil in the two orchards represent extremes in origin, texture, and structure. The soil in the orchard at Hall is correctly designated as Ontario fine sandy loam, a glacial soil which is calcareous at a depth of 22 to 36 inches. The soil appears uniform throughout the orchard, though wide differences in individual tree yields are prevalent. It would seem, therefore, that these differences in tree yield are caused by soil differences not detectable by the ordinary method of profile examination.

The soil in the orchard at Ithaca is classified as a Dunkirk silty clay loam. It is a lake laid soil with an extremely heavy subsoil of tight clay at varying depths. The soils supporting the high and low yielding trees in this orchard are not strikingly different. However, a careful examination of the profiles shows quite clearly that the soil under the better trees is more silty in the subsoil.

The high and low yielding trees at Hall have an average yield index of 119 and 74 respectively. The yield index is expressed in terms of per cent of the average tree yield of the orchard over a 10-year period. The high and low yielding trees in the orchard at Ithaca have produced an average of 7,100 and 4,300 pounds of fruit per tree, respectively, during a 12-year period, 1919–1932.

Results

The redox values were averaged for the different tree groups at the various sampling dates and are shown graphically in Fig. 1. As can be seen from the curves, the lowest E_H values and the greatest difference in E_H are prevalent at the time of the first sampling (April 21) and shortly after. As the season advances and air replaces some of the excess soil water, the E_H rises rapidly and differences between soils becomes less. It will be noted from Fig. 1 that there still remains a significant difference between the soils from the high and low yielding trees on June 12 at Ithaca and as late as July 7 at Hall. How late this difference will prevail depends upon the type of soil and the nature of the season. The data, however, show quite clearly that with the soils studied the effect of excess water in the spring reflects itself in the redox measurements long after normal conditions for aeration have been restored. This lag in the redox potential enables one to identify an imperfectly drained soil much later in the season than would be possible by direct measurements of the ground water. In general the difference between the high and low yielding soils becomes gradually less as the season advances and with the exception of minor fluctuations completely disappears in late summer and early fall. It is evident from the curves that the peak has been reached in September or October and at the later sampling dates there is a definite downward tendency, especially in the case of the lower producing soils.

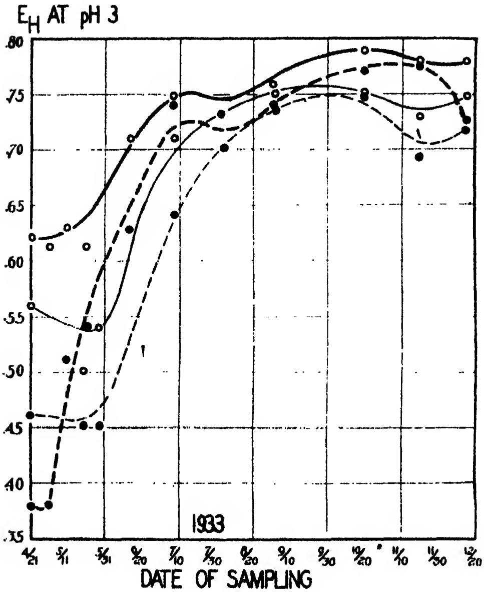

Fig. 1. Seasonal Trend in Redox Potentials of Soil Under High and Low Yielding Trees in Two Orchards

Heavy solid line represents average E_H of 12 high yielding McIntosh trees in a 20-year-old orchard at Ithaca; heavy broken line shows average E_H of 12 low yielding McIntosh trees in a 20-year-old orchard at Ithaca; light solid line shows average E_H of 18 high yielding Baldwin trees in a 35-year-old orchard at Hall; light broken line shows average E_H of 18 low yielding Baldwin trees in a 35-year-old orchard at Hall.

In using the oxidation-reduction potential as an indicator of drainage conditions, it must be kept in mind that the redox value is not a

constant property of a given soil but will vary greatly depending upon the time of sampling and seasonal conditions. In this connection it is also important to point out that no definite value will serve to distinguish between good and poor soils of all types. Thus it is seen that the low producing soil at Ithaca on May 20, has a redox value higher than the better soil in the orchard at Hall while there still exists a significant difference between high and low yielding soils in the same orchards. These soils represent extremes in geological origin and texture so it is probable that values obtained on a certain date would be comparable for all soils of the same general type, especially if the sampling was done in April or early May.

This study is not sufficiently extensive to justify any general conclusions. However when it is considered that large differences in redox values are obtained on high and low yielding soils within the same orchards where ordinary profile examination reveals small difference, it would seem that such a measure is of considerable value in ascertaining the value of a soil for orchard purposes.

The writer is indebted to Richard Bradfield for technical assistance.

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The Breeding of Grapes for Juice Purposes[1]

By Richard Wellington, *Experiment Station, Geneva, N. Y.*

THE production of seedlings for juice purposes has been due in part to chance and in part to planned experiments. Whether the origination was planned or not makes little difference in the final product, altho the latter method is deemed more scientific. In this brief paper, I simply wish to call attention to a few successes, a few failures, and to a few possibilities.

To date over 20,000 grape seedlings have been set for fruiting and about three-fourths of these have fruited. Without question many seedlings that might have proved valuable to the wine and unfermented juice industries have been discarded and valuable unknowns have not yet been selected. In the future we expect to prevent these losses as we are now cooperating with juice manufacturers, chemists and pure culture experts.

The European grape breeders, as you know, have spurned the *Vitis labrusca* varieties as parents for direct producers and have used mainly *V. aestivalis, V. vulpina,* and *V. rupestris* types. There is no question but that the pure labruscas are altogether *too foxy* to be used as parents but many of our so-called American varieties, which are really hybrids between *V. labrusca* and *V. vinifera* produce desirable wine grapes when intercrossed or crossed with viniferas. In other words the undesirable foxy aroma is eliminated at least to a high degree in gametic segregations. Possibly improved labrusca hybrids will never be used in California, Southern Europe and other places where viniferas thrive but in the northern grape regions, the grape breeder should not overlook these types. This does not mean that *V. aestivalis, V. vulpina* and other species should be neglected in producing wine grapes.

In 1901, Ozark, a *Vitis aestivalis* type was crossed with Isabella, a *V. vinifera-V. labrusca* hybrid, and gave a seedling that produces a good red wine. This seedling No. 4534 is now being closely observed by F. E. Gladwin at Fredonia, N. Y. Norton, another *V. aestivalis* type has given no seedlings of particular merit and the same can be said of the *V. vulpina* types, such as Bacchus, Clevener, Clinton, Seibel No. 2, Elvira and Noah, and Hybrid Franc, a *V. vinifera-V. rupestris* hybrid. Unfortunately most of these grapes were crossed with our so-called American varieties rather than with the superior *V. vinifera* varieties. If they had been, the story might have been different. Further, since these crosses were made, excellent direct producers that are superior to the mentioned varieties in many respects, have been obtained and the chances are they will make superior parents. Time and space prohibit an extended discussion of varieties and crosses, but a few that have given desirable progeny will be noted. Winchell crossed with Diamond gave two good wine

[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 28.

grapes, namely Ontario and Ripley. The latter has a slight objectionable flavor when first pressed, but this unpleasantness disappears during the process of aging. Another unnamed seedling of Winchell by Diamond parentage crossed with Brighton gave the Brocton, another promising white wine grape. In crosses between Ontario, Brocton and Ripley and pure *V. vinifera* varieties, many very promising seedlings for wine and table purposes have appeared. Lignan blanc crossed with Ontario produced the Seneca, a pure flavored, early ripening white grape of high sugar content. Seneca is considered very promising by certain wine manufacturers. Station seedling No. 13774, a cross between No. 10606 (Frankenthal precoce x Ripley) and Wayne (Mills x Ontario), No. 13839, a cross between No. 10438 (Bakator x Brocton) x Ontario, No. 13911 (Zinfandel x Ontario), No. 11407 (Chasselas Golden x Brocton), and No. 10608 (Frankenthal precoce x Ripley) were selected in 1933 as possessing distinct merit for wine purposes. Many of these new seedings are apparently hardy, vigorous, and productive and should prove to be of far more value to the wine trade than varieties like Delaware, Dutchess, Elvira, Eumelan, Catawba, etc.

Dunkirk and Hanover are two productive red colored seedlings that also possess merit for wine purposes. The former was derived by crossing Brighton with Jefferson and the latter by crossing Brighton with Niagara. Brighton also made a desirable parent in the cross Brighton by Blauer Portugieser, when 2 out of 8 seedlings were judged as of merit for wine. Blauer Portugieser by Ripley gave 5 wine grapes out of 13, and Bakator by Diamond 2 out of 7. Judging from the few results enumerated and from many other observations, we believe that the use of these superior seedlings for wine making and for breeding will eventually revolutionize the wine industry in the eastern states.

A new black grape, named Westfield in 1930—not the late maturing variety named Westfield that was never introduced to the general public—has proved to be an exceptionally desirable grape for the unfermented trade. According to F. E. Gladwin who produced this grape at the Vineyard Laboratory of the N. Y. Agricultural Experiment Station, by crossing the Herbert with the Concord, the Westfield commanded attention from the first because of its high annual yield, its remarkably uniform clusters, and its very deep-red pigmented skin. The juice expressed, proved to be much more highly colored than that of Concord and in some years showed a depth 12 times greater than the last named variety. Analysis of the juice has shown that year after year its sugar content is several points higher than that of Concord grown under like conditions. Thus far it has been considered by several manufacturers as a most desirable sort for heightening the color of unfermented Concord juice, and its use for this purpose has only been limited because of the supply available.

The clusters are usually borne 4 to the shoot, and each from the base of the cane outward is almost an exact replica of any other. They are medium in size and quite cylindrical. The berries are also me-

dium, round and closely packed in the cluster, but not to an objectionable degree. They are overspread with a rather heavy bloom which adds attractiveness to otherwise attractive clusters. The flesh is firm and enclosed with a rather thick skin so that shipping to considerable distances is possible. The fruit matures approximately at the same time as Concord, and the variety is further characterized by a very uniformly, satisfactory yield from year to year. The original vine yielded 9 pounds the first year of its fruiting, and its production has been as high as 15 pounds in subsequent seasons. Westfield is not a dessert variety in any sense.

Chromosome Number of the Beta Grape

By ERNEST ANGELO and CATHARINE BECKER, *University of Minnesota, St. Paul, Minn.*

THE Beta grape was introduced about 1881 by L. Suelter of Carver, Minnesota. This variety as now grown, according to Brierley and Alderman, is probably *Vitis vulpina* (1). However, Mr. Suelter, writing for the "Minneapolis Freie Presse" of October 18, 1884, explains how he pollinated flowers of selected wild grapes with pollen from Concord (*V. labrusca*) and from the seeds thus produced grew a vine which he named Beta.

Counts were made (using root tips) of the chromosome number of the Beta grape. The count is 38, which is in agreement with the number reported for *Vitis vulpina* by Sax (2) and Ghimpu (3).

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Size Inheritance in Gooseberry Fruits

By A. S. Colby, *University of Illinois, Urbana, Ill.*

In connection with the gooseberry breeding work in progress at the Illinois Agricultural Experiment Station, a study has been made of the relative value of certain varieties as parents in the inheritance of berry size as a desired horticultural characteristic. This report has to do with the transmission of size factors in nine gooseberry varieties, selfed and crossed.

There is some disagreement among horticultural authorities regarding the ancestry of the cultivated gooseberries. Probably most varieties now commonly grown on a commercial scale are hybrids of the American, *Ribes hirtellum*, and the western European species, *R. grossularia*. As a rule, varieties of the latter species bear much larger fruits than do those of American origin, although other characteristics of the American group, such as resistance to leaf diseases, greater vigor and either fewer or shorter spines, may be of potential value in the choice of parents in a breeding program. Most of the varieties chosen for the breeding project were those which seemed, from their phenotypic make-up, to be the best suited for the purposes in mind.

The varieties used included the following: Como, a cross between Pearl and Columbus, and Minnesota No. 96, another seedling, both originated by the Minnesota Experiment Station; Glenndale, a cross between [*Grossularia missouriensis* x Red Warrington x Triumph] and Keepsake, sent out by the United States Department of Agriculture; Rideau, a seedling grown by Dr. William Saunders, of Canada; Carrie, said to be a cross between Houghton and Industry; Downing, a seedling of Houghton; and Transparent, Oregon Champion, and Poorman, of doubtful parentage. Poorman is said to have resulted from the crossing of Houghton and Downing but its fruit and plant characteristics are phenotypically different from what might be expected in such a cross and do not indicate such a relationship.

Other varieties of European origin, including Triumph, Columbus, Industry, and White Smith were either selfed or used as parents in making the crosses but only a small number of vigorous healthy seedlings resulted. While an occasional large fruited plant was found it was often weak and diseased. Several have died. Others have not fruited as yet. For these reasons this group of crosses has not been included in this report.

It is generally recognized that fruit or berry size is a relative term and that fruits of the same variety may vary considerably in size, when grown in different sections of the country, because of differences in weather conditions, and soil type and fertility, as well as in the training system followed and the severity of pruning. In this project the seedling plants were grown under similar conditions in the open, in fertile, well drained soil, and handled as nearly alike as

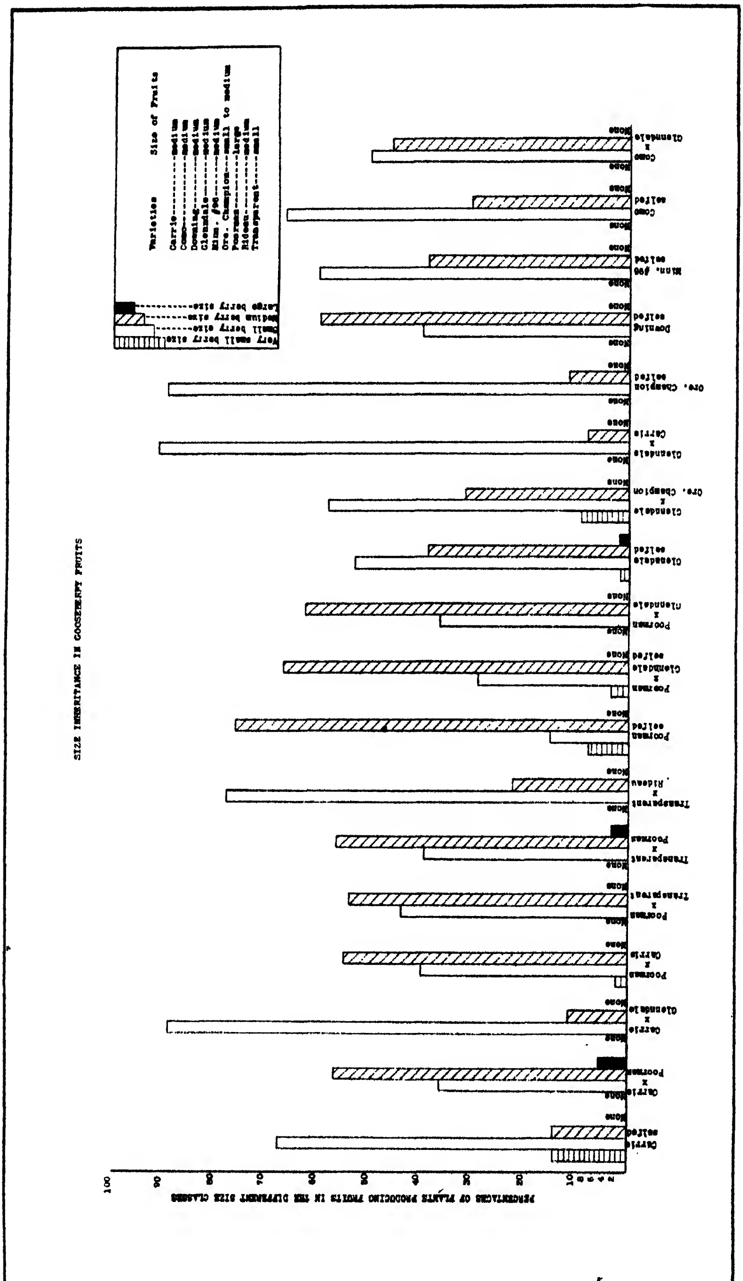

FIG. 1. Relative size of fruits from 800 seedlings resulting from crossing and selfing nine gooseberry varieties. The results are based upon percentages of berries in each size class.

possible. They were trained to the bush form and pruned sufficiently to keep vigorous young canes growing to replace the older wood, which was removed as it became crowded and unproductive. Size records, as expressed in diameters, have been taken over a period of three years, 1931 to 1933, of representative samples of fruit, picked from the individual seedlings. An arbitrary standard for size was followed as outlined below: (a) very small, below 1 cm in diameter; (b) small, 1 to 1.49 cm; (c) medium, 1.5 to 1.89 cm; and (d) large, 1.9 cm and above. A total of 800 seedlings were fruited and classified as to berry size.

Fig. 1 shows the hereditary influence of the varieties used upon the size of the seedling fruits. Percentages of berries rated as very small, small, medium and large are given for the progenies of each of the nine crosses and selfs. It is evident that in most of the progenies studied there is a partial absence of factors for the larger sizes. The appearance, however, of large fruits in 5.2 per cent of the Carrie x Poorman crosses and in 2.4 per cent of the Transparent x Poorman seedlings indicates that at least one of the parents, probably Poorman, carries factors for large size. A self-pollinated Glenndale progeny produced less than 2 per cent of seedlings bearing large fruits. The other parent varieties when either crossed or selfed appeared to introduce those factors which result only in a high percentage of fruits below the size desired in a good commercial berry. The wide variations in size found may be attributed to differences in the genetic constitution of the several varieties and suggest that multiple factors are concerned.

In the material at hand, reciprocal crosses were available in which Poorman, Carrie, and Glenndale were used as either the pistillate or the staminate parent. In none of these combinations was it evident that the larger size factors were influenced in a significant manner.

The results of this work indicate that, of the varieties used, Poorman carried the largest proportion of factors for large berry size. This variety, therefore, appears more desirable than the others in a breeding program where large berry size is sought. Several of the large fruited seedlings are promising, also, from the standpoint of both spinelessness and resistance to the leaf diseases, other characteristics being sought in the project.

The Best Parents in Purple Raspberry Breeding[1,2]

By George L. Slate, *Experiment Station, Geneva, N. Y.*

SEVERAL approaches have been used in the breeding of purple raspberries at the New York State Agricultural Experiment Station. This paper is an attempt to evaluate the methods and to indicate the most promising procedure in future purple raspberry breeding operations. The data presented have been summarized from the raspberry breeding records of the Station which have been accumulating since 1893, when Columbian was selfed and crossed with Cuthbert. Most of the crosses reported have been made since 1920.

The results of attempts to produce purple raspberry seedlings by various combinations of black, red and purple raspberries are shown in Table I. An attempt signifies pollination of at least eight or ten emasculated flowers enclosed in one sack. In many cases 20 or 30 flowers were used and usually three sacks were used in a single attempt. Combinations involving red varieties as pollen parents were generally successful, and many large populations were secured from such crosses. Purple selfed, purple x purple, and (purple x red) selfed were also successful in producing seedlings.

TABLE I—Results of Attempts to Produce Purple Raspberries by Various Combinations of Black, Red, and Purple Raspberries

	Crosses Attempted	Crosses Producing Seedlings	Percentage Producing Seedlings
Black x red	46	34	73.9
Purple x red	21	16	76.1
(Purple x red) x red	23	19	82.6
(Purple x black) x red	1	1	100.0
Purple x purple	7	7	100.0
Purple x self	19	19	100.0
(Purple x red) x self	2	2	100.0
Red x black	60	5	8.3
Red x purple	7	5	71.4
(Purple x red) x black	8	0	——
Purple x black	5	1	20.0
(Purple x black) x black	3	1	33.3
Black x purple	2	0	——

On the other hand, use of the black varieties as pollen parents was generally unproductive. Little success may be expected in breeding purple raspberries unless the red raspberry is used as the pollen parent. The reason for this failure to secure seedlings when black varieties are used as pollen parents has not been determined. Since the

[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 26.

[2]The indebtedness of the writer to S. A. Beach and members of the horticultural department of his time, to R. D. Anthony, and especially to Richard Wellington who made many of the crosses herein reported, is hereby acknowledged.

chromosome numbers of the two species involved, *Rubus occidentalis* and *R. strigosus*, have been shown by Longley and Darrow (1) to be the same, namely, 7 for the haploid phase, incompatibility is not due to differences in chromosome number. Possibly it may be due to partial growth inhibition of black pollen tubes in red styles, ovary and ovule. This failure of the red x black[3] crosses is the more striking because of the complete success of the reciprocal crosses and the fair success obtained in many crosses between more distantly related species of Rubus.

The results that may be expected from those combinations between black, red and purple raspberries that resulted in populations large enough to warrant judgment are shown in Table II. The percentage of seedlings deemed of sufficient merit for further testing is used as a rough measure of the value of a cross in purple raspberry breeding. The selection of a seedling for further testing is made on the basis of its behavior in the original seedling plantation. However, seedlings that are promising at first may be lost later owing to difficulties of propagation, the ravages of virus diseases, or lack of hardiness.

TABLE II—SUMMARY OF MERITORIOUS PURPLE RASPBERRY SEEDLINGS RESULTING FROM VARIOUS COMBINATIONS OF RED, BLACK, AND PURPLE RASPBERRIES. (MANY SMALL POPULATIONS INCLUDED IN TABLE I WERE EXCLUDED HERE)

	Number Crosses	Number Seedlings	Number Selected	Percentage Selected
Black x red	20	2648	196	7.4
Purple x red	22	1112	24	2.1
Purple x purple	7	151	0	—
Purple x self	15	413	4	1.0
Purple x black	2	31	0	—

The combinations producing the highest proportions of promising purple raspberries are the black x red crosses, 7.4 per cent of these being sufficiently meritorious for further testing. All seedlings of merit, instead of only the few best, are tested further, in the hope that some may be found that are unusually resistant or klendusic[4] to virus diseases.

Purple x red crosses produce a few populations with excellent seedlings, but these fail to sucker or to root at the tips. Consequently they are lost.

Crossing purple x purple and selfing of purple results in a miscellaneous lot of seedlings, none of which is red or black. Many exhibit various degrees of sterility; considerable variation in vigor is evident,

[3]The female parent is stated first throughout this paper.

[4]Klendusity is the term recently originated to describe and rate the character of escaping successful inoculation by virus diseases. Degrees of susceptibility by strict interpretation are expressive of internal relations within the plant. Degrees of klendusity are shown by variable rates of spread and are apparently due to external factors in relation to the habits and efficiency of the vector.

and nearly all are decidedly less vigorous than their parents. In fruit characters all are inferior. It should be noted, however, that all but one of the purple x purple crosses involve individuals with the same ancestry. Possibly combinations involving other varieties would be more productive of success. Likewise 6 out of 15 populations resulting from selfed purples involved this same line. The crossing and selfing of purples seems not to be a promising line of attack in breeding purple raspberries.

The number and percentage of promising selections from various variety crosses is shown in Table III. Certain combinations have yielded a much higher percentage of promising seedlings than others. One of the most promising purple crosses is that between Dundee and Newburgh, 24 per cent of its seedlings being of sufficient merit for further testing. The seedlings are generally hardy, vigorous, upright in habit, free branching, and of desirable fruit characters. Dundee x Lloyd George yielded only 0.7 per cent of desirable seedlings. Seedlings from this cross are generally rather sprawling and produce only one or two thick, short canes. Of this cross 16.5 per cent are autumn fruiting, while none of the Dundee x Newburgh cross bears any autumn fruit. In other crosses Lloyd George seedlings lack hardiness and are in many cases susceptible to anthracnose, but desirable fruit characters are numerous. Lloyd George, although unsatisfactory as a parent in breeding purple raspberries, has proved exceptionally good in at least one cross with red varieties.

TABLE III—Number and Percentage of Promising Selections from Various Crosses

Parentage	Seedlings Tested	Percentage Selected
Black x Red		
Smith No. 1 x June	457	7.4
Cumberland x June	289	3.1
Kansas x Empire	38	26.3
Watson No. 1 x Turner	14	—
Gregg x Cuthbert	11	9.1
Rachel x Cuthbert	29	3.4
Plum Farmer x Lloyd George	100	4.0
2593 (Honeysweet x Rachel) x Lloyd George	200	6.5
2635 (Watson No. 1 x Honeysweet) x 2585 (Newman x Herbert)	15	40.0
2635 (Watson No. 1 x Honeysweet) x Lloyd George	50	8.0
3047 (Rachel x Honeysweet) x Lloyd George	75	17.3
3047 (Rachel x Honeysweet) x 2586 (Newman x Herbert)	50	16.0
3205 (Honeysweet x Rachel) x Lloyd George	30	3.3
3212 (Honeysweet x Rachel) x Lloyd George	50	2.0
3214 (Honeysweet x Rachel) x Lloyd George	35	8.5
Gregg x Lloyd George	50	2.0
Dundee x Lloyd George	284	0.7
Dundee x Newburgh	266	24.0
Rachel x Devon	369	2.1
Rachel x Latham	236	5.5

Parentage	Seedlings Tested	Percentage Selected
Purple x Red		
771 (Smith No. 1 x June) x Herbert	7	28.5
655 (Smith No. 1 x June) x Herbert	9	22.2
771 (Smith No. 1 x June) x June	10	—
2004 (167 (Columbian x Self) x Open) x Herbert	28	3.5
2023 (170 (Columbian x Self) x Open) x Herbert	23	13.0
2213 (Kansas x Empire) x Turner	29	—
2233 (Kansas x Empire) x Empire	16	6.2
2342 (788 (Smith No. 1 x June) x June) x Newman	35	—
2319 (655 (Cumberland x June) x Herbert) x Newman	144	—
2326 (771 (Smith No. 1 x June) x Herbert) x Newman	13	—
2317 (655 (Cumberland x June) x Herbert) x Newman	115	0.8
2004 (167 (Columbian x Self) x open) x Lloyd George	70	8.5
2319 (655 (Cumberland x June) x Herbert) x Lloyd George	120	—
2317 (655 (Cumberland x June) x Herbert) x Owasco	38	—
2319 (655 (Cumberland x June) x Herbert) x Owasco	121	0.8
2004 (167 (Columbian x Self) x open) x 2585 (Newman x Herbert)	22	—
2317 (655 (Cumberland x June) x Herbert) x 2585 (Newman x Herbert)	148	0.6
2319 (655 (Cumberland x June) x Herbert) x 2585 (Newman x Herbert)	27	3.7
2319 (655 (Cumberland x June) x Herbert) x 1950 (Empire x Herbert)	32	—
Goodwin No. 1 x 2586 (Newman x Herbert)	50	2.0
2822 (2213 (Kansas x Empire) x Watson No. 1) x 2586 (Newman x Herbert)	25	—
3138 (2023 (170 (Columbian x Self) x open) x Herbert) x 3198 (Newman x Cuthbert)	30	13.3
Purple x Purple		
2028 (170 (Columbian x Self) x open) x 2031 ((170 (Columbian x Self) x open)	10	—
888 (Smith No. 1 x June) x 927 (Smith No. 1 x June)	26	—
927 (Smith No. 1 x June) x 888 (Smith No. 1 x June)	20	—
888 (Smith No. 1 x June) x 967 (Smith No. 1 x June)	39	—
967 (Smith No. 1 x June) x 888 (Smith No. 1 x June)	22	—
927 (Smith No. 1 x June) x 967 (Smith No. 1 x June)	11	—
967 (Smith No. 1 x June) x 927 (Smith No. 1 x June)	23	—
Purple x Self		
548 (Cumberland x June) x Self	22	4.5
Shaffer x Self	8	—
626 (Cumberland x June) x Self	8	—
644 (Cumberland x June) x Self	20	—
1865 (626 (Cumberland x June) x Self) x Self	14	—
2028 (170 (Columbian x Self) x open) x Self	26	—
2208 (Kansas x Empire) x Self	68	4.4
806 (Smith No. 1 x June) x Self	46	—
888 (Smith No. 1 x June) x Self	16	—
884 (Smith No. 1 x June) x Self	16	—
919 (Smith No. 1 x June) x Self	81	—
927 (Smith No. 1 x June) x Self	19	—
967 (Smith No. 1 x June) x Self	14	—
Goodwin No. 1 x Self	25	—
3138 (2023 (170 (Columbian x Self) x Open) x Herbert) x Self	30	—

TABLE III.—*Concluded*

Parentage	Seedlings Tested	Percentage Selected
Purple x Black		
2213 (Kansas x Empire) x Watson No. 1	22	—
2822 (Kansas x Empire) x Watson No. 1) x 3214 (Honeysweet x Rachel)	9	—

Crosses involving Rachel are generally unsatisfactory, none of the seedlings being outstanding and only a few worthy of second test. Nearly all the seedlings from the Rachel x Devon cross show more or less sterility, particularly in the later flowers. Many seedlings of the crosses Rachel x Cuthbert, Rachel x Devon and Rachel x Latham possess short brittle petioles. These are present in enough seedlings to indicate a recessive character.

The percentage of success from red x black crosses is misleading. Of the five crosses resulting in seedlings, populations I and II consisted of one dwarf plant each; III consisted of one purple; IV consisted of three seedlings not described; while V was made up of 10 weak red seedlings which may have been selfs. It is possible too that the other dwarfs may have been selfs since sometimes an anther may be overlooked or an anther may have opened sufficiently to allow a few pollen grains to drop out before or during emasculation. The one purple seedling may have been a contamination for an error in transplanting.

The percentage of success from red x purple crosses also is misleading as the five crosses produced populations of one, one, two, two, and four, or a total of only 10 seedlings. Of these 10 individuals four were red, one purple, three were weak and did not fruit, and two were sterile.

It may be said in general that populations in which a high percentage of promising seedlings appear usually contain the most outstanding seedlings as well. The general level of merit in such populations is usually high. In populations yielding only a few seedlings for further testing, the general level of merit is low and these few selections are rarely outstanding. This tendency has prevailed also in red raspberry, black raspberry, and strawberry breeding at the Geneva Station. Promising crosses should therefore be repeated on a larger scale, since in general, the percentage of crosses giving good results is low.

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The Genetic Constitution of Certain Red Raspberry Varieties in Relation to Their Breeding Behavior[1]

By C. D. SCHWARTZE, *State College of Washington, Pullman, Wash.*

ALTHOUGH the species and varieties of red raspberries have many promising characteristics from the plant breeder's point of view, extensive hybridizing has produced only a few superior seedlings. Results of breeding with other fruits (3) suggests the possibility that more profitable results may be obtained through the isolation and use of varieties which are outstanding in trasmitting valuable characters to their progeny. Information relative to the genetic constitution of red raspberry varieties or indicative of outstanding breeding behavior should, therefore, be of value. The data presented herewith were obtained from approximately 1,800 seedlings of six varieties of red raspberries. The plants were produced in connection with the study of the breeding of red raspberry varieties for hardiness which is being conducted jointly by the Washington Agricultural Experiment Station, Pullman, and the Western Washington Experiment Station, Puyallup.

PRESENTATION OF DATA

The outstanding appearance of the fruits of certain of the red raspberry seedlings as contrasted with the parents suggested the recording of data relative to certain fruit characters such as (a) size; (b) shape; (c) flavor; and (d) color.

Fruit size:—The data pertaining to the inheritance of size of fruit as shown by certain crosses are given in Table I.

TABLE I—SIZE OF FRUIT IN CERTAIN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Large	Medium	Small
Cuthbert x Lloyd George	123	112	3
Cuthbert x King	4	66	25
Cuthbert x Marlboro	—	24	7
Cuthbert x Latham	4	20	2
Cuthbert x Antwerp*	1	8	7
King x Marlboro	—	7	22
Latham x Antwerp	3	31	3
Lloyd George selfed	21	2	—
King selfed	—	1	11
Marlboro selfed	—	17	40

*Antwerp of the Pacific Coast. Fruit medium in size, light red, conic, acid.

The data in Table I show that Lloyd George is outstanding in transmitting large size of fruit to its seedlings. This is especially noticeable in the field because the inbred seedlings are less vigorous than the parent variety. Nevertheless, even the least vigorous seedlings bear fruits which compare favorably in size with those of the parent.

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The data show that Lloyd George is homozygous or nearly so, for large size of fruit. King and Marlboro lose both in size of fruit and vigor of plant when inbred. Hybrids between the two are generally lacking in vigor and in size of fruit. Cuthbert, Latham and Antwerp seem to be heterozygous for fruit size factors.

Fruit shape:—Table II contains the data pertaining to the inheritance of fruit shape as shown by certain crosses.

TABLE II—SHAPE OF FRUIT IN CERTAIN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Hemi-spherical	Round	Round Conic	Conic	Oblong Conic
Cuthbert x Lloyd George	—	—	—	111	134
Cuthbert x King	1	11	45	39	—
Cuthbert x Marlboro	—	2	24	5	—
Cuthbert x Latham	—	3	13	10	—
Cuthbert x Antwerp	—	—	8	8	—
King x Marlboro	11	11	7	—	—
Latham x Antwerp	—	11	21	5	—
Lloyd George selfed	—	—	2	—	21
King selfed	6	6	—	—	—
Marlboro selfed	41	8	8	—	—

Table II indicates that much the same relationship exists for fruit shape as for fruit size. Lloyd George seems to be homozygous for factors producing elongate fruits. Fruits of Marlboro and King seedlings are more nearly round than those of Lloyd George seedlings. The other varieties are intermediate in respect to fruit shape but the predominance of the conic shape indicates that the elongate type such as the Lloyd George is the homozygous dominant. The short type classified as round and spherical probably is the recessive type.

Fruit flavor:—The data indicating the inheritance of fruit flavor in certain red raspberry crosses is shown in Table III.

TABLE III—INHERITANCE OF FLAVOR OF FRUIT IN CERTAIN CROSSES

Cross (and Reciprocal)	Insipid	Sweet	Subacid	Acid
Cuthbert x Lloyd George*	10	34	41	37
Cuthbert x King	8	27	50	11
Cuthbert x Marlboro	2	12	10	7
Cuthbert x Latham	3	6	14	3
Cuthbert x Antwerp	2	1	10	3
King x Marlboro	6	1	1	12
Latham x Antwerp	7	3	5	18
Lloyd George selfed	—	—	8	15
King selfed	6	1	3	2
Marlboro selfed	22	6	14	11

*Reciprocal not represented.

In Table III "sweet" includes both the flavors that are predominantly sweet and those that are a combination of sweet and sour. That Cuthbert is the best parent of the six studied from the standpoint of

flavor is shown by the predominance of the more desirable flavors in the crosses of Cuthbert with other parent varieties as contrasted with the small percentage of good flavors in the crosses in which Cuthbert is not one of the parents. Lloyd George transmits high acidity to its progeny. This quality may be of value in breeding new varieties for processing and freezing. The chances of obtaining hybrids with desirable flavors are much greater when the parent varieties have the best flavors.

Fruit color:—Data relative to the inheritance of fruit color in certain crosses are shown in Table IV.

TABLE IV—COLOR OF FRUIT IN CERTAIN RED RASPBERRY CROSSES

Cross (and Reciprocal)	Red	Yellow†
Cuthbert x Lloyd George	241	33
Cuthbert x King	80	—
Cuthbert x Marlboro	31	—
Cuthbert x Latham	27	—
Cuthbert x Antwerp	16	—
King x Marlboro	87	—
King x Latham	26	—
King x Antwerp	74	—
King selfed	17	—
Marlboro x Antwerp	97	—
Marlboro x Victory*	124	—
Marlboro selfed	105	—
Victory selfed	7	5
Latham x Victory	50	—
Latham selfed	12	—

*Thought to be identical with Cuthbert.
†Including those turning pink at maturity.

Table IV indicates that Cuthbert and Lloyd George are heterozygous for fruit color factors whereas Latham, King, Antwerp and Marlboro are homozygous. The results obtained with Lloyd George agree with those reported by other investigators (2). Certain crosses (1) with Marlboro, however, have indicated that this variety is heterozygous. The variety listed as Victory is thought to be identical with Cuthbert.

Sex as a factor in red raspberry breeding:—Another factor which has a direct bearing on the breeding behavior of red raspberry varieties is that of sex. Investigations with the European species, *Rubus idaeus* L. (2) have shown that individual plants may be male, female, hermaphrodite or neuter. Lloyd George was found to be a homozygous hermaphrodite. Our Lloyd George seedlings are all hermaphrodites. Single sexed and neuter plants have appeared in certain crosses with each of the other varieties studied, indicating that they are heterozygous for sex factors. Since male and neuter plants set no fruits and females require cross pollination, the selection of homozygous hermaphrodites for parents will greatly increase the percentage of desirable seedlings so far as sex is concerned.

Conclusions:—These studies seem to justify the following conclusions: 1. Commercial varieties of red raspberries may be either homozygous or heterozygous for several characters that are important to the plant breeder. 2. Classification of a large number of varieties on the basis of degree of homozygosity would be of value for future breeding purposes. 3. There is a possibility of developing superior breeding stock by selecting inbred and hybrid seedlings which are homozygous for certain valuable characters even though these seedlings may be useless for commercial purposes. 4. The Lloyd George variety is superior as a parent because of its homozygosity for large size of fruit, desirable shape of fruit, high acidity and hermaphroditism. 5. A genetic analysis of *Rubus strigosus* Michx. and a study of the genetic relationship involved in hybridizing *R. strigosus* and *R. idaeus* would be of value in view of the fact that many of our commercial varieties are hybrids of the two species.

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A Study of Blackberry and Dewberry Varieties as Breeding Material

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THERE has been a gradual increase during the 30-year period from 1899 to 1929 in the number of acres and total yield of blackberries and dewberries in the state of Texas (3), ranging from 2,394 acres in 1899 with a yield of 2,701,750 quarts to 7,676 acres in 1929, yielding 5,474,598 quarts. Statistics reveal further that during the latter part of this period there has been a decided increase in the number of cases of canned blackberries and dewberries produced in several other states (4). At the same time Texas has not shown a proportionate increase in canned products compared with the increase of fresh fruit. This relative decrease in canned products was brought about by the lack of a variety or varieties which would meet the competition of the Evergreen blackberry, grown primarily in Washington and Oregon. Those varieties adapted to Texas conditions had certain undesirable fruit characters when placed on the market as a canned product. The outstanding one was the failure of certain varieties to stand up in the pack more than a few months which resulted in a mushy product. Also, the high acidity of certain varieties reduced their value as a canned product since additional sugar was required.

Therefore, the principal problem of blackberry growing in Texas is the finding or breeding of varieties whose product will meet the demand of the consumer. In order to satisfy the grower such varieties should have a heavy annual production. The plants should set their fruit sufficiently late to avoid damage from late frosts and yet mature the fruit before the hot dry summer months. The plants should be of upright growth to facilitate ease of cultivation and harvesting and to insure clean fruit. The upright plants should have a heavy lateral growth that is sufficiently open to facilitate harvesting. It is desirable to have a plant that sets a large number of fruits to the cluster rather than many clusters with only a few fruits each. There should be a minimum number of prickles on the main stem and lateral branches and also on the leaf petiole and dorsal surface in order to provide optimum harvesting conditions. In order to satisfy the demands of the consumer the pack must present a lustrous appearance. The individual fruits should have a texture that is neither too hard nor too soft. They should have a pleasing flavor with a fairly high sugar content and sufficient acidity to keep from tasting flat, as well as having seeds that do not detract from the palatability of the fruit.

In view of the need for such a variety an extensive collection of the more widely recognized varieties of blackberries and dewberries of the United States was begun during the year 1928. This collection has been extended until at present it includes fifty-six varieties of blackberries and eighteen varieties of dewberries. A few of these are duplicates secured from different regional sections of the United States.

In beginning the varietal study, two lines of procedure were adopted. The first was to establish the relative merits of available varieties for East Texas and record those characters distinguishing each variety in order to make recognition easy. The second was a comprehensive study of the behavior of individual varieties and their established characters in order to ascertain definitely their value as breeding material.

Observations and measurements made on this material have shown repeatedly that certain individual characteristics of a variety are sufficient to prohibit its being used for commercial purposes in this section. Such characters are equally undesirable when considering the variety as a possible parent plant. This study of the behavior and characteristics of the varieties has definitely associated certain characters with particular varieties or groups of varieties. The problem thus becomes one of combining the features of different varieties, where this is possible, in order to secure types that will be commercially successful when grown under East Texas conditions. Notes on the characteristics of the varieties from the standpoint of breeding material follow.

The Rogers dewberry loses the greater part of its crop each season because it is inclined to set its fruit too early. The plant is undesirable on account of its small prostrate viny growth. The Evergreen blackberry appears to utilize its resources of plant food and energy in maintaining its growth during the winter months. This variety is also very susceptible to the "Double Blossom" disease. The Himalaya blackberry is exceptionally vigorous but sets only a few partially developed fruits which mature late in the season. Cory's Thornless does not promise to be of any value as breeding material as only a few fruits have set and matured since being placed in the collection. It has also proved to be easily infected with the "Double Blossom" disease. The Thornless dewberries have produced very low yields and weak plants, proving to be worthless, with the possible exception of a single factor to be mentioned later. All thornless varieties appear to be susceptible to the leaf spot disease caused by *Cylindrosporium rubi* Ell. and Morgan, and to anthracnose. The latter disease is partly responsible for a very low yield of fruit from these varieties as a large percentage of the new cane growth is killed by it during the current season. Crystal White and Iceberg, novelty blackberry varieties, are undesirable on account of the appearance and mushy condition of the packed product. The Pink blackberry has a very low resistance to low temperatures as the canes are often frozen to the ground. When not affected by low temperatures it produces a dense vigorous cane growth consisting of numerous laterals with many secondary laterals covered with sharp hooked spines which increases the difficulty of harvesting. A fair crop is produced but the small size and light color of the fruit makes it unsatisfactory for commercial production. The Mammoth is closely related to Cory's Thornless and likewise is very susceptible to the "Double Blossom" and anthracnose diseases. It produces a fair cane growth in early spring but fails as hot dry weather begins. The canes are of prostrate

habit and bear a greater number of prickles than any other variety in the collection. Mt. Pocono, Joy, Macatawa, Marvel, and Louisiana Selection No. 2, in general, are not adapted to East Texas, as their plant growth is weak and the yield is very low. Other varieties, such as Stoneshardy, Snyder, Ward, Taylor, Early King, Badger, and Mersereau, set fair crops of fruit but the yield and quality are low because of late maturity. All late-maturing varieties have proved to be more susceptible to nematode infestation than the earlier-maturing varieties.

Certain other varieties have desirable characters which might be combined to produce a more suitable kind for East Texas. Of three varieties selected as outstanding for pollen parent material, Hall's Lawton, a selection of the Lawton blackberry, is one of the more promising. Its cane growth is upright, vigorous, shows little susceptibility to disease and nematode attack, and has a heavy lateral growth that is sufficiently open to facilitate harvesting operations. It propagates readily from root cuttings and sends forth a plentiful supply of new canes each season. It sets and matures a heavy crop of fruit annually which matures from early to mid-season. The fruits are medium to large, firm, of fair flavor but high in acidity, and have large seeds. The canned product is pleasing in appearance and stands up exceptionally well over a long period.

The Youngberry was selected as a second pollen parent primarily because of the size and excellent flavor of its fruit. This highly desirable flavor is so attractive that it meets with ready approval as either a fresh fruit or canned product. Although this particular flavor is obtainable from several sources (1) only the Youngberry and Loganberry were available from our plantation at the beginning of this work. The Loganberry was not used on account of its lack of vigor and late maturity of fruit. The exceptionally large size of the Youngberry fruit makes it the outstanding variety for this character when compared with the other varieties in the collection. However, the seeds are conspicuous and the fruit is soft, causing it to break down even with a small amount of handling. The cane growth is vigorous and develops large primary laterals from near the base of the main stem. These exceedingly long primary laterals will in turn produce long secondary laterals in case of injury or pruning. It sets and matures a heavy crop of fruit annually, with a medium-early maturity. It propagates readily from tip-layering and cuttings from current season's growth.

The third pollen parent selected was Crandall's Early, a variety that is vigorous and a heavy producer with semi-erect canes. The fruiting branches droop sufficiently to facilitate harvesting. The fruit is moderately large, firm, of excellent flavor, matures at midseason, and has seeds of medium size. This variety propagates readily from root cuttings and tip-layering. Darrow (2) states that the Crandall's Early and Macatawa are names for the same variety of berry. In establishing our plantation the highly successful Crandall's Early was obtained from a single source and the poorly adapted Macatawa from two other sources. The two plantings of the Macatawa from dif-

ferent sources have the same varietal characteristics but do not show any identifying similarity to the planting of Crandall's Early.

Other varieties having desirable characters are being used as female parents and include Early Harvest, Haupt, McDonald, Thornless Austin, Austin, Rogers, Dallas, Rathbun, Lucretia, Kenoyer, Blowers, Alfred, and Eldorado. The Early Harvest possesses the desirable characters of prolificacy, low acidity, and very small inconspicuous seeds. However, its fruits are small. Its upright cane growth is vigorous and has few small prickles. The plants tend to set a larger crop than they can mature, resulting in a portion of the fruit drying on the canes. The Haupt blackberry was selected for its earliness, vigor of cane growth, and heavy production of fruit that is fairly firm and of good quality.

The McDonald is early, vigorous, very productive with medium-sized fruit, and has a thin skin and soft flesh. The quality is good but there is uneven ripening of a small percentage of the drupes. This variety has the habit of setting very few fruits on clusters which are distributed over the main stem and primary laterals. It is self-sterile and should be planted with another variety which blossoms at the same time. Thornless Austin is used as breeding material for the single factor of freedom from prickles on both canes and leaves. This character may show up in crosses of other varieties since it was found to be recessive in McDonald by Ness (5). The Austin dewberry has a vigorous prostrate cane growth with many long laterals, is very early, and produces a heavy crop of firm fruit fairly good in quality. The crop is matured over a short period of time, a feature desirable in commercial canning. The extreme earliness and firm fruit of Rogers are the two characters of possible breeding value. The Dallas blackberry, one of the long-recognized standard varieties for Texas, has a semi-procumbent vigorous cane growth and produces a heavy yield of firm, medium-sized berries of midseason maturity. The value of the Dallas as breeding material would seem to be its character for high yield combined with other desirable characters. The Rathbun was also chosen for its high production, small, firm, sweet, fruit, small inconspicuous seeds, few prickles, and upright cane growth. The Lucretia dewberry was selected for its extra large fruit, although its large seed, prostrate growth, lack of plant vigor, and poor quality of fruit are objectionable. The Kenoyer has an upright vigorous cane growth with the habit of setting a large number of fruit per cluster, the majority of which are toward the ends of a few long laterals, thus facilitating harvesting. The entire crop matures within a short period of time. The fruit is medium-large, firm, and of high quality with seeds of medium size. The Blowers, Alfred, and Eldorado, all similar types, are fairly productive and have semi-erect canes that put out new growth from the base. Although late in maturing, the plants have the ability to mature a crop of medium-large fruit that is firm, sweet, and of good quality. These, as with other late-maturing varieties, are susceptible to nematode attack, which, with the lack of heavy production, prevents their being used for commercial plantings.

Since the commercial varieties of Rubus are relatively heterozygous two general types of breeding methods are being followed: first, varietal crosses, growing large populations for purposes of selection and, second, inbreeding of selected varieties with later crossing of the inbred strains. Crossing of certain selected varieties holds promise of giving earlier results but the number of crosses will necessarily have to be limited in order that sufficiently large populations can be grown to secure individuals having a desirable combination of characters. The selected progeny will be increased by root cuttings or by other methods of asexual propagation. Inbreeding of selected varieties will permit the use of a larger number of individuals from each variety for the isolation of the desired characters. Although this system will necessarily be slower than with the varietal crosses, it affords an opportunity to accumulate those genetic factors for certain characters useful in a commercial variety. The crossing of the inbred strains should restore any vigor lost through inbreeding. A further advantage from this system will be the possibility of securing the desired types by back crossing the inbred strains.

To date, seed from a large number of desired varietal crosses, and selfed seed from selected varieties have been secured. As a whole the fruits have been well developed, maturing sound firm seed. The McDonald blackberry failed to set fruit from fifty-two self-pollinated blossoms. Complete failure was recorded for a smaller number of selfs of the Crandall's Early. An F_1 self of the Hall's Lawton failed to set fruit from twenty-two self pollinations, although the parent plant gave a high percentage of selfed fruit.

The breeding of blackberry and dewberry varieties presents the problem of acquiring material that will impart the factors for type of plant, growth, and fruit necessary to commercial berry production in this section. The collection of varieties under study has provided material with these characters. It is hoped that these characters can be combined to produce varieties that are better adapted to the East Texas area than any of the commercial varieties now available.

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Chromosome Number and Self-Fertility in Prunus virginiana and P. pennsylvanica

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ONE of the possible methods of producing hardy cherry varieties for Minnesota conditions is the cross-breeding of the cultivated sweet and sour cherries, which are not reliably hardy in Minnesota, with hardy native species, such as *Prunus virginiana* L. and *P. pennsylvanica* L. As the ease with which different species of plants can be crossed is often indicated by their respective chromosome numbers, a cytological study was made of these two native species. Other workers have studied the chromosomes of the cultivated cherries. Darlington (1) found from 17 to 19 chromosomes in the somatic cells of 16 sweet cherry varieties examined. Kobel (2) found eight pairs of chromosomes in the pollen mother cells of eight varieties of sweet cherry. In the sour cherry and "duke" cherry varieties, Kobel (2) and Darlington (1) both found 16 pairs of chromosomes in the pollen mother cells.

In this study, buds of both *Prunus virginiana* and *P. pennsylvanica* were taken from trees growing at University Farm, St. Paul, Minnesota. Whole buds were killed in Bonn's Flemmings and in Bouin's B15 and stained with gentian violet. Pollen mother cells were also examined and preliminary chromosome counts made with aceto-carmine smears.

Sixteen pairs of chromosomes were found in the pollen mother cells of *Prunus virginiana*. Ten counts were made at metaphase I and five at anaphase I. In one other cell, only 15 pairs of chromosomes were seen. Three cells showing non-orientation and a fourth showing non-conjunction were found among 131 cells at metaphase I. In *P. pennsylvanica* eight pairs of chromosomes were counted in the pollen mother cells and 16 somatic chromosomes were found in vegetative parts of the buds.

From these chromosome counts, it may be predicted that *Prunus pennsylvanica* may cross with the sweet cherry somewhat more readily than with the sour and "duke" cherries, and that *P. virginiana* may cross more readily with the sour and "duke" cherries than with the sweet cherry. In this connection it should be noted that the sweet cherry, sour cherry, "dukes" and *P. pennsylvanica* all belong taxonomically to a different subsection of the genus Prunus from that to which *P. virginiana* belongs, and the latter species, therefore, probably will not cross with the sour and "duke" cherries as easily as their like chromosome number would indicate.

To determine the self-fertility of the two wild species, branches of both were enclosed with coarse muslin to prevent insect visits and the flowers were self-pollinated with a camel's hair brush.

One tree of *Prunus virginiana* set one fruit on each of four racemes and no fruit on 70 racemes when self-pollinated, or an average of .054 fruits per raceme. Under open pollination, 100 racemes on the

same tree set an average of 1.860 ± .136 fruits per raceme. A second tree set two fruits on each of two racemes and none on 13 racemes or an average of .267 fruits per raceme when self-pollinated, and an average of 3.230 ± .470 fruit per raceme on 30 racemes when open-pollinated. Though this species is self-fertile, its fertility was much reduced by self-pollination. *P. pennsylvanica* also proved to be self-fertile, producing 25 fruits from 1935 self-pollinated flowers, or a set of 1.3 per cent. This was slightly less than the 2.8 per cent set, or eight fruits from 283 flowers, from open pollination.

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Additional Facts in Regard to the J. H. Hale Peach as a Parent in Breeding Work

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AT the annual meeting of the Society in 1932, a paper was presented upon the J. H. Hale peach as a parent in peach crosses (1). In the limited time allowed it was possible to present only a few of the outstanding facts. This paper is, therefore, a continuation of that presented in 1932. In the first paper, attention was called to the fact that the J. H. Hale peach is largely a combination of recessive characters. When crossed with other combinations of characters termed varieties, namely, the Iron Mountain, Chinese Blood, Japan Dwarf Blood, S. P. I. 55564, Amarillo Tardio (55836), and the species *Prunus (Amygdalus) kansuensis,* the progeny very closely resembled the pollen parents. This occurred also when J. H. Hale was crossed with Bolivian Cling (S. P. I. 36126), N. J. 10416, N. J. 27116 and Mexican Honey (S. P. I. 32373). Prominent characters of J. H. Hale listed in 1932 as recessive are: (a) semi-dwarf compact tree habit, (b) yellow flesh, (c) large size of fruit, (d) round form of fruit, (e) short, sparse pubescence and (f) firm melting flesh.

RESULTS OF BREEDING WORK

J. H. Hale x Mexican Honey (S. P. I. 32373):—The Mexican Honey peach discussed in this paper was obtained from the U. S. Foreign Seed and Plant Introduction Bureau, as indicated by the S. P. I. number. It is so distinct in type from the other varieties reported as dominant over J. H. Hale that the results of the cross are reported in some detail.

The Mexican Honey is a small, distinctly pointed, oval-conic to oblong-conic, white-fleshed freestone. The tree has a characteristic upright spreading habit with rather slender twigs and rather narrow leaves. A cross with J. H. Hale, by Connors, in 1928 produced 84 trees which were planted in orchard form in 1930. The tree habit of each seedling closely resembles that of Mexican Honey. No trees bearing sterile flowers were found. During the summer of 1932, 78 trees matured fruits, all of the oval to oblong-conic, distinctly pointed form typical of the pollen parent. Some of the trees produced fruits slightly larger than Mexican Honey and the red coloring of some was more complete. The flavor of the fruits on some of the seedlings was modified by the cross although the majority were sweet and resembled Mexican Honey.

Since lack of funds precluded sugar and acid determinations, trees were classified according to their relative sweetness and acidity of the fruits as determined by taste. Of the 78 trees which fruited, 24 produced distinctly sweet fruits, 21 medium sweet, 7 slightly acid, 21 distinctly acid and 5 were unclassified because too few fruits ripened.

In the J. H. Hale x Mexican Honey cross, fruit characters such

as small size, oval to oblong-conic form and white flesh color were again dominant and also the upright, spreading and rather large tree habit.

J. H. Hale x Paragon (S. P. I. 43135):—In the paper presented in 1932, mention was made of a cross of J. H. Hale by Paragon, a semi-dwarf, yellow-fleshed, melting clingstone, introduced by the Foreign Seed and Plant Introduction Bureau of the U. S. Department of Agriculture. This variety was developed from an Elberta pit planted by Mr. H. R. Wright of New Zealand. It is the only named variety of the 42 used at the New Jersey Station as pollen parents in crosses with J. H. Hale which possesses much the same recessive characters as the J. H. Hale. It is not surprising, therefore, that it was the outstanding cross to give progeny resembling the J. H. Hale in tree habit and fruit characters. It was also reported in 1932 that the New Jersey Station had obtained progeny with tree and fruit characters similar to J. H. Hale as a result of selfing Elberta; and further that the Station had dwarf and semi-dwarf sports of Elberta. This is evidence to the effect that both the Elberta and J. H. Hale varieties possess recessive factors for dwarfness of tree habit, large fruit size, roundness of form, firm melting flesh and short pubescence.

J. H. Hale x Lemon Cling:—A cross of J. H. Hale x Lemon Cling was made in 1928 and trees set in the orchard in 1930. The first fruits were produced in 1932. The Lemon Cling develops a very large, spreading tree habit at New Brunswick. The progeny obtained from the J. H. Hale x Lemon Cling cross, however, were distinctly more dwarf and compact in habit, like the J. H. Hale. The fruits also resembled the J. H. Hale in form, red color and short pubescence but the flesh texture was watery melting instead of firm melting. This makes them unsatisfactory for commercial purposes.

Elberta Type in J. H. Hale Crosses:—In New Jersey the Elberta peach is rather easily distinguished from J. H. Hale by its larger and less compact tree habit, the more oval shape of the fruits, the longer pubescence, the more prominent suture and the somewhat lighter and less extensive red skin color. There is considerable variation in the form of fruits of the Elberta even on the same tree at times. These variations were classified into six types by the author in 1925 (2).

Among a total of 85 trees obtained from a cross of J. H. Hale x Cumberland in 1926, a considerable number produced fruits of the Elberta type. The parentage of Cumberland was Belle x Greensboro. Elberta type fruits were also obtained in some degree in a cross of J. H. Hale x Rosebud, and a large percentage from crosses of J. H. Hale x Lizzie and J. H. Hale x Salberta.

It is well-known that the form, pubescence, and edible quality of some varieties of peaches may vary considerably from season to season, even in the same orchard. A number of factors may affect form of fruit as reported from time to time in several New Jersey publications (2, 3,4, 5).

High temperatures in the early part of the growing season favor the development of more pointed forms. Any factors which check or inhibit the downward translocation of foods tend to cause the development of split pit fruits. High carbohydrate Elberta trees produced fruits of a form different from those developed by high nitrogen trees at New Brunswick in 1929. Fruits developed on high nitrogen trees retain their pubescence much better than those on high carbohydrate trees. In the latter case the pubescence is weathered off to a considerable degree. Fruits of varieties such as Elberta and Golden Jubilee are commonly distinctly flatter under drought conditions. Fruits produced on trees affected with "little peach," and the so-called "peach buttons" commonly vary distinctly from normal fruits of the same variety. Time and space permit only brief mention of these facts in this paper.

Effect of weather at New Brunswick, 1933:—It is seldom that the standard varieties of the peach are winter-injured at New Brunswick, sufficiently to cause serious killing of fruit buds or injury to the sap-wood sufficient to modify or inhibit growth. Abnormally warm weather during November and December 1932, however, caused the fruit buds of the peach to swell and later a minimum of —3 degrees F on February 13 killed a high percentage in varieties such as J. H. Hale and Elberta. The weather during the early spring of 1933 at New Brunswick, was also sufficiently cool to prevent the trees from growing with normal rapidity for some weeks following blooming. The behavior of the trees and fruits indicated that they were higher in carbohydrates than is normally the case. The effect of the slight winter injury and the cool weather of early spring on the form, pubescence and edible quality of the fruits in some of the J. H. Hale peach crosses was very marked.

J. H. Hale x Chili:—In 1932, it was reported that the progeny of a cross of J. H. Hale by Chili all closely resembled the pollen parent, which produces fruits that are heavily pubescent, only medium in size and of an oblong-oval to oblong-conic form. This was true for 1930, 1931, and 1932, but 1933 was a marked exception to the rule. On many trees the fruits were distinctly flatter and closely resembled Elberta of a medium size and flat shape. The cavity and form of the fruits around the stem still resembled Chili. The pubescence was very short, as a rule, and rather thin as compared to the heavy pubescence of Chili. The flavor also resembled that of a rather ordinary Elberta, much more than in any previous year. Not a single tree, however, produced fruits of the round J. H. Hale form. Any experienced peach grower who might have been asked in 1933 to guess the parentage of the seedlings would in all probability have mentioned Elberta as one. Trees of Chili planted a short distance from the J. H. Hale x Chili progeny produced fruit of normal form in 1933 and just as heavily pubescent as in 1932.

J. H. Hale x Eclipse:—The variety Eclipse was developed at the New Jersey Experiment Station as a result of the self-pollination of Belle in 1915, by Connors. Belle is white-fleshed, but heterozygous and Eclipse was only one of a number of seedlings which produced

yellow fruit. Progeny obtained later as a result of the selfing of Eclipse greatly resembled that variety in both tree and fruit characters. The fruit of Eclipse as it develops at New Brunswick is medium in size and oval to oblong-conic and a true freestone. It is rather round about the middle at New Brunswick and seldom flat. In some sections of New Jersey, however, the fruits are sometimes slightly flat. The pubescence is short and thin, the skin thick and tough, the flesh firm and of a mild acid, attractive flavor, free from bitterness. It is not astringent and has been reported by several as superior to Elberta and J. H. Hale for freezing fresh. In 1925, it was thought that a cross of J. H. Hale by Eclipse might result in an increased size of the Eclipse fruit and the cross was made. A total of 200 trees was obtained and planted in an orchard at New Brunswick in 1927. Good crops were obtained in 1930, 1931 and 1932. The fruits produced were, in all cases, equal in size to Eclipse and, in many cases, somewhat larger. They were attractive in appearance and of a somewhat oval shape. The edible quality of the fruit produced by each seedling was at least slightly superior to Elberta but the flavor resembled that variety more than it did Eclipse. In some seasons at New Brunswick, in promising seedlings of this cross the flesh was inclined to adhere to the pit and the fruits were not true freestones like the pollen parent. The flavor of most was mildly acid and free from bitterness. Not a single tree, however, resembled J. H. Hale in its slightly dwarf compact habit and large, round, firm fruits.

Behavior was different in 1933:—The weather conditions in the winter of 1932–33 at New Brunswick have already been described. The J. H. Hale by Eclipse progeny were variable in hardiness. Some, like J. H. Hale, produced only a few fruits while others produced a good crop, as did Eclipse. An outstanding fact, however, was that the fruits on nearly all of the trees resembled Elberta in form and flavor much more than in any previous year. They were more broad and flat, more acid and some were more bitter and astringent than formerly.

New Jersey 10416:—A seedling obtained as the result of a cross of Lola x Arp in 1916, bore small round-oval, yellow-fleshed fruits, with flesh melting and rather watery. During one season the skin of the fruits was almost as free of pubescence as a nectarine and the dots of the skin were unusually large and conspicuous. During the past few years the fruits of N. J. 10416 have been characterized by rather long pubescence. In 1933, however, the fruits of 10416 were again almost free from pubescence and conspicuous for the large numerous whitish dots in the skin.

Varieties Differ:—Some varieties in the large collection at New Brunswick do not differ greatly in form or pubescence regardless of seasonal conditions. Others like those mentioned may vary greatly from season to season and in different regions.

Round, Flat Type:—Among the progeny obtained from crosses of Elberta x Early Crawford, Chinese Cling x Oldmixon, J. H. Hale x Primrose, and J. H. Hale x Delicious, are trees which produce fruits that are quite round or round truncate but quite flat through

the cheek diameter. Some of the fruits bulge on one side but generally the bulge is below the middle line. This tendency was more pronounced in 1933 than in some previous years. In contrast, Elberta, although it has a winged pit, generally bulges near the middle of the fruit.

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The Germination of "Non-Viable" Peach Seeds[1]

By O. W. Davidson, *Experiment Station, New Brunswick, N. J.*

A PEACH breeding project has been in progress at the New Jersey Experiment Station since 1914. In the course of this work, Connors (1, 2) found that the seeds of varieties ripening before Carman either are non-viable or possess only a very low degree of viability. Carman seeds were found to be about 15 per cent viable, whereas the seeds of Belle, and peaches ripening after this variety, are usually about 85 to 95 per cent viable. Because of this lack of viability in the seeds of early peaches, it has been a practice in peach breeding work to use as seed parents only those varieties that produce a reasonably high proportion of viable seeds. If two early-ripening parents could be combined in peach breeding, the obtaining of commercially desirable, high quality, early peaches apparently would be facilitated greatly.

Artificial Culture Used

Tukey (6) has shown that the seeds of varieties of sweet cherries which ripen their fruit in less than 50 days after full bloom either abort, or fail to complete the development of their embryos and, therefore, are non-viable. He developed a method of artificial culture (5) by which he has matured and germinated such sweet cherry embryos.

During the summer of 1933, peach seeds of several varieties were collected in the Experiment Station orchards at New Brunswick from July 7 until August 30 and were cultured by the methods described by Tukey (5). The seeds were placed in sand and in agar cultures provided with nutrients.

None of the various agar media tried was satisfactory, since the germinating seedlings seldom produced roots in these cultures. In sand cultures, however, the seeds turned green in 5 to 14 days and germinated in from 14 to 21 days.

A nutrient solution in the ammonium sulphate series of Jones and Shive (4) having the following molar proportions of salts: 0.00633 KH_2PO_4, 0.0073 $Ca(NO_2)$, 0.00237 $MgSO_4$, and 0.0014 $(NH_4)_2SO_4$ is very satisfactory for the growth of peach seedlings in sand culture. This solution when modified to include ½ p. p. m. of iron as $FeSO_4$ and 1 per cent glucose, was found to be as suitable for the germination of peach seeds in sterile sand culture as was the modified Crone solution used by Tukey (5). The Jones and Shive solution is much simpler to prepare than is the Crone solution.

Although light is not necessary for the germination of normal peach seeds, nevertheless, with the cultural treatments used in this work, light appears to be needed for the development of abortive peach embryos. It is possible that the photosynthetic activity of the coty-

[1]Paper of the Journal Series, New Jersey Agricultural Experiment Station, Division of Horticulture.

ledons may supply carbohydrates in forms that are necessary for growth but not furnished by the nutrient solutions used.

Temperatures between 20 and 30 degrees C favor the development and germination of abortive peach embryos. Cultures kept below 25 degrees C, however, showed considerably less contamination by molds than cultures kept at temperatures between 25 and 30 degrees C. Nevertheless, regardless of the temperature used, the extent to which contamination occurs in sand cultures started in an ordinary room warrants the use of a transfer room or a transfer chamber for this work.

Results Obtained

The past season's work on this problem is regarded as preliminary. The results obtained, however, may be used advantageously in peach breeding where the seeds are to be cultured artificially.

In the accompanying table, some of the varieties used in this work are classified according to the percentage of germination given by their seed when cultured artificially during the season of 1933. The seeds of all the varieties listed, except Elberta and 41SD, are normally non-viable. A few, probably not more than 5 to 10 per cent, of the seeds of 41SD are normally viable.

TABLE I—Germination of Peach Seeds Artificially Cultured

Approximate Percentage of Seeds Germinated			
75 or More	50 to 75	50 or Less	No Germination
Dewey	Elberta	Buttercup	Greensboro
Golden Jubilee	Marigold	Duke of York	Mayflower
Oriole	Japan Dwarf Blood	Gordon	Early Wheeler (Red Bird)
Rosebud	Yellow Greensboro	95423	168425
Sunbeam	99325	165625	172425
41SD	171625	169425	
88425*			

*Numbers refer to unnamed N. J. Station seedlings.

The seeds of ripe Mayflower peaches collected in southern New Jersey on July 7 were very poorly developed. The embryos ranged from 1/8 to 3/8 inch in length, and failed to germinate, or even to turn green, when cultured. Early Wheeler (Red Bird) seeds from fruits almost ripe on this date had much larger embryos than did Mayflower seeds, and although they swelled and, in some cases, turned green, they failed to germinate. Greensboro seeds from fruits ripening about July 20 possessed embryos which apparently were developed fully. These embryos turned green in 5 to 7 days, swelled considerably, but did not germinate. In general, seeds from peaches ripening before July 20 in New Jersey seldom germinated when cultured artificially. Those from peaches ripening between July 20 and 25, or the seeds taken from immature fruits at this time, germinated poorly. After July 25, however, the seeds from ripe and from imma-

ture fruits usually germinated well. Mature Elberta seeds cultured by this method likewise germinated without having been after-ripened.

After-Ripening Not Necessary for Germination of Viable Peach Seeds

It is interesting to observe that dormancy in peach embryos differs markedly from that of sweet cherries. Tukey (5) found that normally viable sweet cherry seeds taken 40 to 50 days after full bloom would germinate in a few days when cultured artificially, while such seed failed to germinate when allowed to develop further. Elberta peach seed, however, although it is normally viable, will germinate in 2 to 3 weeks when taken from mature fruits. Moreover, it will germinate in the same time when cultured from at least 38 days before until at least 15 days after fruit maturity. These results may have been anticipated, since Crocker and Barton (3), working with seeds of Elberta (mid-season) and of Lemon Free (late mid-season) peaches, found that embryos removed entirely from their seed coats would germinate within 2 weeks when placed on moist filter paper and held at room temperature.

Dormancy in the seeds of mid- and late mid-season varieties of peaches at least would seem to involve processes of condensation in their reserve foods, and possibly metabolic changes in them some time later than 2 weeks after the fruits mature. The information at hand, however, does not preclude the possibility that the seed of late varieties of peaches may reach a state of dormancy before fruit maturation —resembling sweet cherry seed in this respect.

After-Ripening Necessary for Normal Growth

Although after-ripening is not necessary for the germination of all mature, viable peach embryos, it appears to be required for the normal growth of the seedlings. During the season of 1933, the peach seedlings developed in artificial cultures from that year's embryos grew very slowly and abnormally. All of the plants, those from viable as well as those from abortive embryos, were abnormal. The leaves were unusually small, wrinkled, and in many cases, they were peculiarly curled. Some of the tip leaves lost their chlorophyll, remained small, partly folded, and became very rigid. The apical meristem of some plants enlarged considerably and turned yellow. Root growth, however, was not affected seriously by the erratic behavior of the plants, since most of them developed fairly good root systems. Top growth stopped about October 20, at which time the largest seedling had a stem not more than 4 inches in height.

Crocker and Barton (3) reported that peach embryos which have not been after-ripened germinate poorly and that the resulting seedlings grow more slowly than do embryos and seedlings from after-ripened seeds. These investigations and others indicate that the aberrant growth of the artificially cultured seedlings was due to failure to supply conditions necessary for the after-ripening of the seeds.

To ensure normal growth, therefore, the plants were hardened in a cold frame and then, as conditions would permit, they were stored at temperatures between 0 and 6 degrees C. It is expected that the low temperature treatment given to the dormant plants will stimulate normal growth.

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Anomalous Embryos of Cultivated Varieties of Prunus With Particular Reference to Fruit Breeding

By H. B. TUKEY, *Experiment Station, Geneva, N. Y.*

ABSTRACT

The complete paper will be found in the *Botanical Gazette* for March 1934.

THE frequency of occurrence and the character of anomalous embryos is recorded from examination of 27 cultivated varieties of peach (*Prunus persica* Stokes) and 17 cultivated varieties of cherry (*P. avium* L.). Supernumerary cotyledons were found in 5 varieties of sweet cherry and 4 varieties of peach, all but one of these having three cotyledons and one having four. Such embryos may germinate and develop into seedlings. The suppression of one cotyledon in whole or in part was found in varying degrees, ranging from the fuller development of one cotyledon than the other, to the complete suppression of one cotyledon, in the latter case the developing cotyledon being suggestive of the enfolding single cotyledon of corn (*Zea mays*), a monocotyledon. In other instances the cotyledons may arise undiverged to give the appearance of a closed collar. Other anomalous shapes are described. In comparison with the wild species type, the highest frequency of anomalous forms occurred among the cultivated varieties. These observations serve to emphasize the heterozygous condition in cultivated varieties of peach and cherry, and suggest that plant breeders might find it profitable to begin their studies of segregation by an examination of the seed and embryo.

Xenia and Metaxenia in the Bartlett Pear

By W. P. TUFTS and C. J. HANSEN, *University of California, Davis, Calif.*

IN 1931 (6) we concluded after two seasons' observations that environment and genetic constitution were the outstanding factors determining the shape of Bartlett pears as grown on the Pacific Coast. At that time we stated that "data secured during the 1931 season with Bartlett pears seem to indicate that there is no correlation between seed content and the ratio of length to diameter of the fruit." This conclusion was based on the fact that long and short fruits were found with both low and high seed counts, but these fruits were produced in different districts. In 1931 in only one orchard (Sutter County, California) did we have both a high and a low seed count together with data for the relative length of the fruit (Table II, 1931). In this orchard in 1931 the seed count apparently had no influence on the shape of the fruit. Recent recalculation of data secured in 1918 showed that cross-pollination very materially decreased the length to diameter ratio (L/D) (see Table I). No seed counts are available for these crosses, but in view of our experience in other experiments, the fruit resulting from cross-fertilization probably had a larger number of seeds per fruit than that resulting from self-fertilization.

TABLE I—BARTLETT PEAR POLLINATIONS, VACA VALLEY, 1918

Pollen	Number of Fruits	Ratio L/D
Bartlett, open pollinated*	6	1.38
Bartlett	41	1.44
Howell	47	1.25
Winter Nelis	61	1.25
Easter Beurré	72	1.22
Comice	73	1.28

*No provision for cross-pollination.

In 1932 and 1933 measurements and seed counts were made in the same Sutter County orchard reported in 1931 (see Table II). It

TABLE II—SEED CONTENT AND L/D RATIO, SUTTER COUNTY, ORCHARD X

Season	Number of Fruits	L/D Ratio	Number of Seeds per Fruit	Remarks
1931	100	1.20	5.7	Cross pollinizers present
	100	1.21	1.6	No pollinizers present
1932	100	1.20	6.6	Cross pollinizers present
	100	1.29	2.5	No pollinizers present
1933	100	1.24	8.0	Cross pollinizers present
	100	1.38	3.0	No pollinizers present

will be noted that there was during the last two seasons an apparent correlation between the number of seeds per fruit and the L/D ratio.

Since occasional reports (2, 3, 4, 5, 7) have appeared which seem to indicate that the shape of apples and pears is influenced by the pollen parent, and since our own data (Table II) had been conflicting it

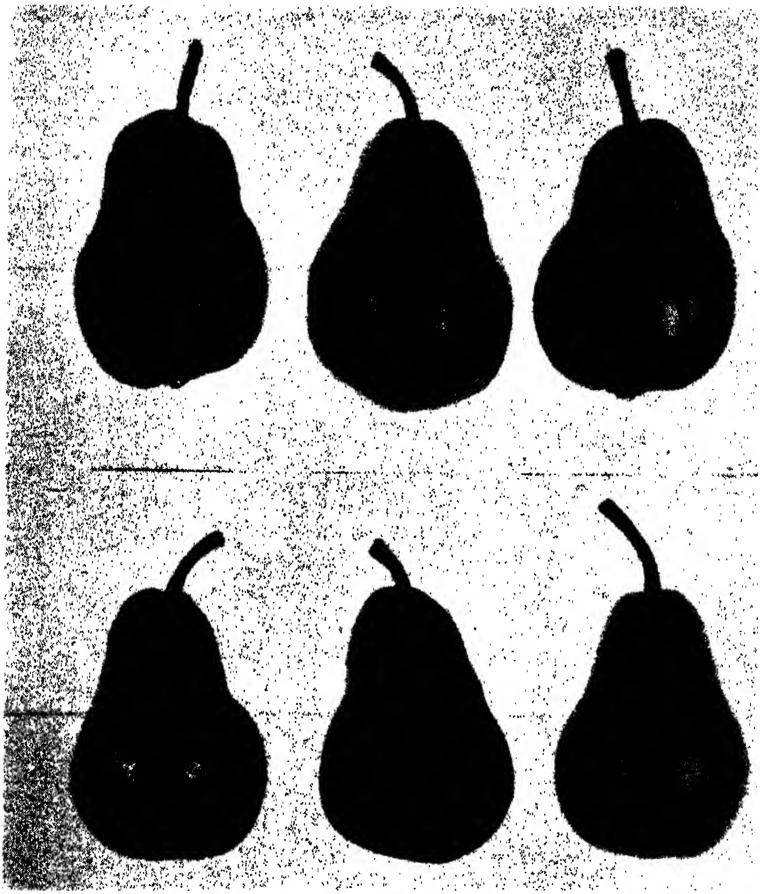

FIG. 1. Self-pollinated Bartlett pears: upper row calyx intact; lower row, calyx and portion of receptacle removed by emasculation process, showing no appreciable change in shape by the use of these methods.

seemed desirable to study further the effect on the Bartlett fruits of pollen from various other varieties of pears.

The experimental work was done in two orchards in Santa Clara County. The Bartlett pears in orchard A (that of Mr. E. A. Nelson) are always longer than those in orchard B, due probably to a genetic difference (6). Data in Table IV illustrate this difference.

To permit making a large number of crosses a rapid method of emasculation was used in which the calyx and a small bit of receptacle with stamens attached were removed with the fingers. Since this method might conceivably cause certain deformities and since the shape of the fruit, as measured by the ratio of length to diameter (L/D), was to be considered, it seemed prudent to emasculate some flowers by removing the stamens with tweezers, leaving the receptacle and calyx intact. Table III presents figures which show that the L/D ratio of fruits, resulting from self-pollination and from crossing with Easter Buerré, was not significantly changed by the method of emasculation (see also Fig. 1). Accordingly, finger emasculation (removal of calyx) was used on the remaining crosses, and the following discussion refers to fruits resulting from flowers emasculated by this method. Einset (1) found that removal of the calyx in the emasculation process produced a smaller set of apples than leaving the calyx intact. Data in Table III show that under the conditions of this experiment, Bartlett pears respond in the same manner.

TABLE III—BARTLETT PEAR POLLINATION, SANTA CLARA VALLEY, 1933

Pollen	Orchard A				Orchard B			
	Number Flowers Pollinated	Per cent Matured	L/D	Average Number Seeds per Fruit	Number Flowers Pollinated	Per cent Matured	L/D	Average Number Seeds per Fruit
Bartlett (Calyx removed)	1,298	12.2	1.37	.4	1,135	5.2	1.11	1.8
Bartlett (Calyx intact)	475	24.2	1.31	.03	—	—	—	—
Easter Beurré (Calyx removed)	717	21.3	1.24	6.8	1,090	26.8	1.03	6.7
Easter Beurré (Calyx intact)	557	35.0	1.25	6.7	—	—	—	—
Beurre Hardy	857	22.2	1.29	3.5	—	—	—	—
Comice	1,229	23.5	1.21	7.1	983	26.6	.97	8.7
Winter Nelis	987	21.7	1.20	8.0	1,039	24.4	1.01	7.7
Anjou	715	29.0	1.17	8.6	980	20.8	1.03	8.0
P. Barry	—	—	—	—	1,068	24.6	1.01	8.5
Beurré Bosc	—	—	—	—	1,073	32.9	1.04	8.6

It is evident from the L/D ratios in Table IV that the pollen parent has influenced the shape of the fruit. However, examination of the data with respect to the number of seeds formed seems to indicate that this variation in shape may be due to the ability of the particular pollen to produce seed rather than to metaxenia. There seems to be a negative correlation between the L/D ratio and the number of seeds. For example, in orchard A the fruits resulting from self-pollination have the smallest number of seeds and the largest L/D ratio, while the fruits resulting from a cross with Anjou have the largest number of seeds and the smallest L/D ratio. It is interesting

to note that pollen of P. Barry and Buerré Bosc, two varieties which produce exceptionally long fruits did not produce longer pears than pollen of short varieties such as Anjou, Easter Buerré, and Winter Nelis.

TABLE IV—L/D RATIO AND NUMBER OF SEEDS IN HAND POLLINATED BARTLETT PEARS

Pollen	Diameter (mm)	Length (mm)	L/D	Average Number Seeds per Fruit	Number Fruits Measured
	Orchard A				
Bartlett	50.5	69.2	1.37	.4	150
Beurré Hardy	55.1	71.3	1.29	3.5	150
Easter Beurré	55.3	68.4	1.24	6.8	106
Comice	58.5	70.8	1.21	7.1	150
Winter Nelis	58.2	70.0	1.20	8.0	150
Anjou	59.5	69.6	1.17	8.6	150
P. Barry	—	—	—	—	—
Beurré Bosc	—	—	—	—	—
	Orchard B				
Bartlett	53.5	59.2	1.11	1.8	59
Beurré Hardy	—	—	—	—	—
Easter Beurré	61.6	63.3	1.03	6.7	150
Comice	61.4	59.7	.97	8.7	150
Winter Nelis	64.6	65.0	1.01	7.7	150
Anjou	58.2	59.9	1.03	8.0	150
P. Barry	58.2	58.9	1.01	8.5	150
Beurré Bosc	59.3	61.4	1.04	8.6	150

Table V contains the coefficients of correlation between number of seeds and L/D ratio for some of the crosses. There is a fair correlation except in the case of the Easter Buerré cross in orchard B. The Winter Nelis cross in orchard A may or may not be considered to show a significant correlation.

TABLE V—COEFFICIENT OF CORRELATION—BETWEEN NUMBER OF SEEDS AND (A) L/D RATIO OF FRUIT, (B) DIAMETER OF FRUIT, (C) LENGTH OF FRUIT*

Pollen	(a) Number Seeds and L/D Ratio	(b) Number Seeds and Diameter	(c) Number Seeds and Length
Orchard A			
Beurré Hardy	—.40±.046	.60±.035	.14±.054
Comice	—.28±.051	.40±.046	.18±.053
Winter Nelis	—.19±.053	.004±.055	—.11±.054
Easter Beurré	—.27±.051	.25±.052	—.02±.055
Orchard B			
Easter Beurré	—.09±.055	.48±.042	.35±.048
Winter Nelis	—.24±.052	.25±.052	—.02±.055

*150 fruits from each cross used in the above calculations.

The coefficients of correlation betwen the number of seeds and diameter of fruits and between number of seeds and length of fruit (see Table V) were also determined in an effort to find out whether it was the diameter or length, or both, that varied with the number of seeds. With one exception, the diameter is increased with an increase in the number of seeds; the length, however, with one exception, is not influenced significantly by seed count. The correlation coefficients in Table V were calculated on populations which varied within narrow limits as to number of seeds per fruit. For example, if the average number of seeds was 8, very few fruits were found with less than 7 seeds. To obtain a population with a seed count varying from 0 to 10 it was necessary to combine fruits from different crosses. In 300 fruits taken at random from selfings, and crosses with Anjou and Buerré Hardy in orchard A the coefficient of correlation between number of seeds and L/D ratio was —.75 ± .017, between number of seeds and diameter .82 ± .013, and between number of seeds and length .15 ± .038. These data, although possibly open to criticism because the fruits were from three crosses, support the conclusion that there is a negative correlation betwen the number of seeds and the L/D ratio and a positive correlation between the number of seeds and the diameter and that the length is practically independent of the number of seeds.

It seems probable that if metaxenia with respect to shape of fruit does occur in the Bartlett pear in the crosses studied, its effects are not of great magnitude and are masked by the effect of the number of seeds. Other possible effects of metaxenia such as color could not be detected.

TABLE VI—Length, Breadth, and Weight of Bartlett Seeds (200 Seeds Measured Except Where Noted)

Pollen	Orchard A			Orchard B		
	Average Weight (mgs)	Breadth (mm)	Length (mm)	Average Weight (mgs)	Breadth (mm)	Length (mm)
Winter Nellis	29.8	3.97±.009	7.88±.015	29.4	4.06±.012	8.10±.016
Easter Beurré	29.9	4.02±.009	7.88±.014	28.7	4.07±.012	8.13±.016
Comice.....	30.4	4.10±.011	7.92±.015	28.2	4.10±.013	7.91±.015
Anjou......	29.8	4.02±.010	8.22±.014	28.4	4.08±.012	8.03±.016
Beurré Hardy	31.5	4.00±.010	8.09±.014	—	—	—
P. Barry....	—	—	—	28.4	4.05±.012	7.98±.016
Bosc........	—	—	—	26.5	4.04±.010	7.77±.014
Bartlett.....	34.7	4.13*±.019	8.09±*.027	29.1	4.18†±.017	8.17†±.022

*63 seeds. †100 seeds.

Seeds from the crosses discussed above were dried and stored under uniform moisture conditions. Later their breadth and length were determined to the nearest tenth of a millimeter by means of a special caliper. These measurements were repeated in the case of about two-thirds of the crosses by a method in which the magnified (X 30) image of the seeds was projected on a calibrated scale. Since the

results obtained by the two methods were comparable, only the measurements obtained with the caliper are included. Examination of the data in Table VI discloses differences in length and breadth of seed which are perhaps statistically significant and the result of xenia. However, the greatest differences are not large and may be due to some unconsidered factor. The average weights of the seeds resulting from the different crosses are also included in Table VI. There is little variation in the average weights of the seeds except that heavier seeds apparently resulted from self-pollination in orchard A This may be the result of the extremely small average number of seeds per fruit (.4 per cent).

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Metaxenia in the Apple and Squash[1]

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SEVERAL European investigators have recently reported positive metaxenial effects in the apple. In 1931 Nebel (1) found that the pollen had a direct influence on the size, shape, and color of this fruit. From additional studies (2) he concluded that the acidity of the cell sap was also influenced. Experiments were started at this station in 1932 to determine whether metaxenial effects in the apple would be of practical importance to growers in this section.

On two Ingram trees short lateral branches which had several strong clusters were selected to bear the fruit. Two flowers on each of the three best clusters were emasculated and sacked, and all others flowers removed. Pollen from the Wealthy and Ben Davis varieties was used equally on each tree. After all terminal growth had ceased, leaves or fruits, as the case might be, were removed, so as to leave at least 25 full sized leaves in the immediate vicinity of each fruit. The rest of the tree set a heavy crop, which was allowed to ripen without being disturbed.

In 1933 this experiment was repeated with the same varieties, but different trees were used. The leaf area per fruit was adjusted as before, but 50 leaves were left adjacent to each fruit, and the fruits with their leaves were separated from the rest of the tree by ringing. Two Golden Delicious trees were treated in the same manner.

The Ingram fruits resulting from Ben Davis pollen were superior both years. In the first year there was a difference in the average weights of almost 20 per cent. The significance of this figure was impaired by the small numbers of fruits and the difference in seed numbers. The second year the difference in weights was only 8 per cent, but this figure is highly significant because of the greater numbers of fruits and the smaller difference in the average numbers of seeds.

The results from the Golden Delicious fruits were negative. The average weights were practically the same. (See Table I).

Since there has been some work to indicate that metaxenial effects are shown by certain of the cucurbits (3), experiments were made with several varieties of pumpkins and summer squashes. The plants, which were grown under greenhouse conditions, reached normal size, and the fruits equalled in size those grown under field conditions.

In the first experiment, pollen from the varieties Big Tom and White Bush Scollop was used on pistillate flowers of the White Bush Scollop. The first normally developed pistillate flowers to open were used. In most cases, the first flower set readily, but it was practically impossible to secure a second fruit on the same plant due to inhibition of further development of the main stem.

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 376.

The second experiment was performed with the same kinds of pollen on pistillate plants of the Acorn variety. The vines were allowed to grow until they were nearly 9 feet tall and had about 50 leaves before any of the pistillate flowers were pollinated. They were not used then unless two normal flowers with ovaries of nearly the same size and on the same plant were open on the same day. These two flowers were pollinated at as nearly the same time as possible with the two kinds of pollen. In this way, it was hoped that the fruits of each pair would be as nearly alike as possible, except for the source of pollen.

TABLE I—Average Weight and Seed Number of Fruits From Different Pollens

Pistillate Variety	Pollen Variety	Number Fruits	Average Number Seeds	Average Weight (Gms)	Difference in Weight (Gms)
			Apples		
Ingram.........	Ben Davis	36	6.14±.27	74.7±2.5	14.4±3.1
1932	Wealthy	28	5.15±.40	60.3±1.9	
Ingram.........	Ben Davis	118	6.7	67.5±0.102	4.8±0.106
1933	Wealthy	123	7.0	62.6±0.104	
Golden Delicious	Ben Davis	32	8.6	143.8	0.5
	Wealthy	28	8.4	144.3	
			Squash		
White Bush.....	White Bush	17	130.0	645±38	
	Big Tom	17	112.0	706±37	61±53
Acorn..........	White Bush	14	155.0	305.	
	Big Tom...	14	139.0	306.	1.0

In all instances the fruits were allowed to remain on the vines until the seeds had fully developed, which was about one month after they had reached their full size. They were weighed immediately after being harvested, and were then stored until the seeds were removed.

If, in the first experiment, any metaxenial effects were produced by these two kinds of squash pollen, they could not be detected. Any such effects that may have existed were overshadowed by the other factors which were responsible for variations in the fruits and seeds. In the second experiment an effort was made to reduce the number of variables to a minimum. No differences in the pairs could be determined by general observation, except for a slight difference in size. The pairs were identical in shape and color. No differences could be detected in the quality or color of the flesh. The mean differences in weights between the pairs were not significant when the odds were computed by "Student's Method" for interpreting paired experiments.

It is probable that those metaxenial effects which might be demonstrated are not of general practical significance in commercial horticultural operations. Although the presence of embryos is necessary for securing a commercial set of fruit on certain plants, their value in increasing the desirable qualities of fruits is doubtful, especi-

ally on those plants where there is little competition between the fruits for food materials.

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An Unusual Leaf Variation of the Apple[1]

By A. P. French, *Massachusetts State College, Amherst, Mass.*

BUD variations affecting the fruit of the apple are numerous but a change in the form of the leaf appears to be very rare. Even Shamel and Pomeroy (1) in their summary of bud mutations in the apple report no variations of the leaf. The one herein illustrated was discovered by the author in the nurseries of Chase Brothers Company of Rochester, New York, during the summer of 1930.

Fig. 1 shows the original tree (B)—a 1-year Red Astrachan whip —on which this variation occurred, as compared with a normal whip (A) of the same variety. All the leaves of Tree B originating on wood below the arrow are normal Red Astrachan leaves, while all those above this point are so different that they scarcely resemble apple leaves. Careful examination of the bark in the region where this change must have taken place disclosed no evidence of any injury. This fact, coupled with the fact that the variation has been propagated, leads to the conclusion that this variation is chimeral or mutational in nature.

Fig. 2 permits a detailed comparison of the types of leaves borne on this tree. Leaf A is a normal Red Astrachan taken from the unaffected part of the tree. Leaves B and C represent the extremes of type found on the sporting part of the tree during the summer of 1931 when it was two years old. As might be expected—due to the reduction in leaf area—the shoot growth on the affected part of the tree was considerably less vigorous than normal growth of the Red Astrachan variety during that season.

During the summer of 1931 one of these sporting branches was brought back to Amherst, and from it ten consecutive buds were set in the nursery. Since each of these ten buds was produced in the axil of a sport leaf, one might have expected similar growth to develop from each. This, however, was not the case. Buds No. 1, 3, and 10 failed to grow; Nos. 2, 5, 6 and 7 produced normal Red Astrachan whips while only buds No. 4, 8 and 9 perpetuated the leaf variation of the parent tree. Since these last three buds were borne on the same side of the shoot—the apple having a 2/5 leaf arrangement—it would seem that there was an uneven distribution of the sporting tissue in this particular bud stick. It is of interest to note that at one point on the tree from bud No. 4, where a bud stick was removed last year, two shoots have developed side by side, of which one is a normal Red Astrachan while the other has typical sport leaves. The budding records to date suggest that in distribution this variation behaves similarly to that reported by Gardner, Crist and Gibson (2) dealing with color variation in the Bartlett pear.

The behavior to date of the original tree is also of interest. After

[1]Contribution No. 183 of the Massachusetts Agricultural Experiment Station.

FIG. 1. (A) Normal Red Astrachan whip, (B) sporting whip of the same variety showing change in leaf from above the arrow.

growing in the nursery 2 years it was dug, shipped to Amherst and stored for spring planting. At the time of planting it was given a normal pruning for a 2-year tree, which included the removal of all terminal buds, but plenty of wood which had borne sport leaves the previous summer was left. The tree made very little growth during

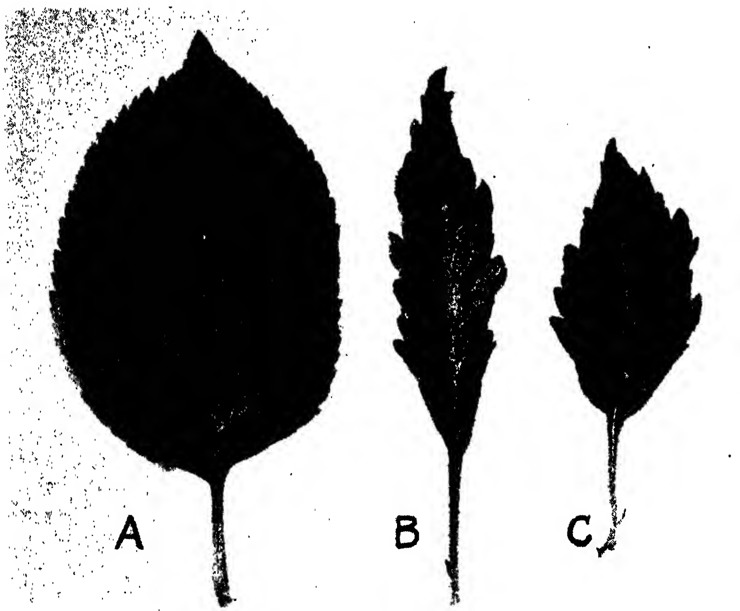

FIG. 2. (A) Normal Red Astrachan leaf, (B) and (C) types of sport leaves from tree B in Fig. 1.

that summer none of which showed sport leaves. During the past summer, which was its second in the orchard, satisfactory growth was made but still all of the leaves produced were normal Red Astrachan. This tree was sufficiently identified in the nursery to exclude any probability of the wrong tree having been sent to Amherst. But just why it has behaved in the above mentioned manner during its 2 years in our orchard is a question.

A similar leaf variation was found by Dr. J. K. Shaw in 1932 in a Connecticut nursery. It occurred on a 1-year McIntosh whip and was quite similar to the one discussed herein. Unfortunately this tree died in the process of removal from the nursery to the orchard as a 1-year tree.

That such variations in apple leaves are rare is evidenced by the fact that only these two cases have been discovered in the past 12 years during which time we have examined for trueness-to-name not less than 10,000,000 nursery apple trees.

It is hoped that future studies may throw additional light on the nature of this variation.

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The Origin of the Pomoideae

By Karl Sax, *Arnold Arboretum, Harvard University, Cambridge, Mass.*

THE Pomoideæ constitute one of the four subfamilies of the Rosaceæ. Its most important genera are Malus, Pyrus, Eriobotrya, Cydonia, Chænomeles, Amelanchier, Cratægus, Cotoneaster, and Sorbus. The Pomoideæ form a distinct subfamily of rather closely related genera. The relationships of the various genera, and the origin of the subfamily, have been studied from the standpoint of cytological, crossing, and grafting affinities.

The morphological similarity of many of the genera is reflected in the ease with which grafts can be made between different genera. Mr. William Judd of the Arnold Arboretum has made a considerable number of inter-generic grafts, using root stocks of Malus, Pyrus, and Cratægus. On commercial Malus root stocks, growth was obtained from scions from Pyrus, Mespilus, Chænomeles, Photinia, Cotoneaster, and Aronia. On Pyrus root stocks, growth was secured with scions from Amelanchier, Cratægus, and Mespilus. Root stocks from various species of Cratægus produced growth in scions of Mespilus, Pyrus, Cydonia, Chænomeles, Cotoneaster, Sorbus, Photinia, and Aronia. These grafts are now 3 years old and have made good growth in most cases. Aronia grafted on Cratægus has produced a plant about 6 feet tall which fruited abundantly during the past season. Professor J. G. Jack, of the Arnold Arboretum, informs me that he has fruited Pyrus on Cratægus stock.

The affinities between different genera are indicated also by generic hybrids. Hybrids have occurred between Cratægus and Mespilus, Sorbus and Aronia, Pyrus and Sorbus, Amelanchier and Sorbus and Pyrus and Cydonia. In at least one of these generic hybrids, Sorbus x Aronia, the chromosomes pair regularly, and the F_1 is fertile. Inter-generic hybrids seem to be confined to rather closely related forms, but the fact that crosses do occur shows a close relationship between certain genera.

All genera of the Pomoideæ have the same basic chromosome number (1, 8). Most species have 17 pairs of chromosomes, but triploid and tetraploid species and varieties are found in the larger genera, especially in Cratægus, Malus, and Cotoneaster. This basic chromosome number is unusual in the Rosaceæ. In the other subfamilies the basic numbers are 8 and 9 for the Spiroideæ, 8 for the Prunoideæ, and usually 7 for the Rosoideæ, although 9 pairs of chromosomes are found in two small genera (10).

The chromosome numbers found in the Pomoideæ, as compared with those in the other genera of Rosaceæ, naturally suggest that this distinct subfamily has been derived from ancestors with a lower chromosome number. Darlington and Moffett (2) have concluded that the basic number in "Pyrus" is 7, "four of which appear four times, and three, six times." The evidence that Pyrus is "a trebly

hexasomic tetraploid" is based on the supposed multivalent association of chromosomes at meiosis, the occurrence of secondary pairing, and the frequent recovery of 41 chromosomes in seedlings from triploids. Although Darlington and Moffett describe and picture numerous cases of quadrivalent and sexivalents at meiosis in diploids, there is good evidence that such multivalent associations are extremely rare, if they occur at all. In a later paper Moffett (8) finds little evidence of true multivalent pairing at meiosis, although he does describe secondary pairing of chromosomes which, in some cases, produces four pairs of bivalents, and three groups, each with three bivalents. He also finds many more 41-chromosome seedlings from triploids than would be expected on a random distribution of chromosomes. This number is supposed to represent a secondary balance of 34 chromosomes of the normal diploid, plus 7 chromosomes of the original basic number.

The writer has examined the meiotic divisions in a considerable number of genera in the Pomoideæ. The aceto-carmine technique was used, which causes less clumping of the chromosomes than is usually found in sectioned material. In no case was there any evidence of multivalent chromosome association in diploids. Adati (1) also finds only bivalents in various Oriental species of Pyrus. We have found evidence of secondary pairing, but it varies considerably in different genera. It was found to be greatest in Cratægus, Cotoneaster, and Malus, and least in Sorbus, Aronia, and Amelanchier. If, as Lawrence (7) suggests, the degree of secondary pairing is an index of the age of a species or genus, Cratægus should be much younger than Aronia or Pyrus, and still these two genera, when grafted on Cratægus, show unusual vigor and compatibility.

If 7 was the original basic chromosome number of the Pomoideæ and the reduplicated chromosomes are sufficiently alike to produce multivalent pairing in the present diploid species, as reported by Darlington and Moffett, then triploid species should show multivalent association of chromosomes, and univalents should be very rare. Moffett finds a considerable number of univalents in certain triploids, and we have found only trivalents, bivalents, and univalents in triploid generic hybrids. As a rule, about a dozen univalents were observed at meiosis, which is good evidence that the present basic chromosome number in the Pomoideæ is not simply a duplication of an original basic set of 7 chromosomes.

According to Darlington and Moffett, the high frequency of 41-chromosome seedlings from triploids is evidence of a secondary balance of 34 chromosomes, the diploid somatic number, plus 7 chromosomes of the original basic set. Nebel (9) also believes that 7 is the original basic chromosome number, and in his analysis of seedlings from triploids he concludes that the most frequent chromosome numbers are multiples of the primary basic number or combinations of the primary basic number. He finds no excess of 41-chromosome seedlings, and, in fact, the X^2 test shows that the frequency distribution does not differ significantly from the distribution expected on random assortment. The most frequent chromosome numbers expected on a

random distribution of the chromosomes of a triploid would be 42 and 43, but in most triploids the actual mode for gametic distribution is less than the theoretical expectation, because of loss of univalents. It is not surprising, therefore, that the chromosome number most frequently recovered in triploid progeny is about 41. A similar result has been obtained in Nicotiana hybrids by Lammerts (6), who finds an average of 29.2 chromosomes in triploid (24 x 12) progeny instead of 30 chromosomes expected on random distribution with no loss of univalents.

The partial self-sterility of the apples has also been considered as evidence of complex polyploid origin. Crane and Lawrence (3) show that the diploid Prunus varieties are completely self-sterile, while hexaploid species are often completely or partly self-compatible. An increase in self-compatibility would be expected in complex polyploids and perhaps in allotetraploids. Many commercial varieties of apples are somewhat self-fruitful, although none is completely so, and in many cases self-fruitfulness may not depend on self-fertility. Self-sterility in the apple seems to be dependent, to a considerable extent, on environmental conditions, and varieties which are usually self-sterile in one region may be partly self-fertile in other regions (5). The following species of Pyrus and Malus grown at the Arnold Arboretum seem to be self-sterile; *Malus robusta, M. prunifolia, M. floribunda, M. Sieboldii, M. platycarpa, Pyrus amygdaliformis, P. elæagrifolia,* and *P. phæocarpa.* These species may not be completely self-sterile, because only 50 flowers were selfed on each tree, and the work was limited to one season, but self-sterility seems to be almost, if not quite, complete in many species of Pyrus and Malus. Eight species in these genera were found to be partly self-fertile. Although polyploidy would be expected to increase self-sterility, the variation found in the degree of self-sterility need not necessarily be attributed to polyploidy. The different degrees of self-sterility in Malus may be caused by different growth rates permitted by different sterility factors (4), and certain sterility allelomorphs may completely suppress self-fertility only under certain environmental conditions.

There is good evidence that the Pomoideæ are of polyploid origin. But the absence of multivalent chromosome associations in "diploids," the behavior of chromosomes in triploids, and the great variability in secondary pairing in different genera, clearly indicate that this subfamily has not been produced by a simple reduplication of 7 basic chromosomes, "four of which appear four times, and three, six times."

It seems quite probable that the Pomoideæ are of allopolyploid origin, and were produced by hybridization between different primitive forms in the Rosaceæ, followed by chromosome doubling. Numerous cases of allopolyploidy produced by wide species or generic hybridization, followed by chromosome doubling in F_1, have been reported in recent years. A cross between species with 8 and 9 chromosomes—numbers characteristic for many genera of the Rosaceæ—might be expected to produce an entirely new type of plant. The chromosomes would be sufficiently homologous to permit hybridization between the

two species or genera, but not sufficiently homologous to insure pairing and the production of fertile gametes. Chromosome doubling would permit pairing of homologous chromosomes, there would be some secondary pairing due to remote affinities, fertility would be restored, and a new type of plant would be produced with 17 pairs of chromosomes. The new type would tend to breed true and would not produce fertile intermediate forms when back-crossed with the original parents. The genetic behavior of such an allopolyploid would be expected to be complex because of the duplication of similar, but not necessarily identical, genetic factors. The duplication of multiple and complementary factors is also a probable cause of genetic complexity. The differentiation of genera might be attributed to a multiple origin of similar types, although it seems more probable that the Pomoideæ were derived from a simple ancestral type, and that mutation and minor changes in chromosome morphology have been responsible for generic and species differentiation. The present genera of the Pomoideæ are closely related, as indicated by morphological characteristics, grafting relationships, the occurrence of generic hybrids, and the remarkable similarity in chromosome number and chromosome morphology.

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Phosphorus in Alternate-Bearing Sugar Prunes[1]

By Cecil Compton, *Citrus Experiment Station, Riverside, Calif.*

THE investigation here reported presents seasonal changes of phosphorus in mature alternate-bearing Sugar prune (*Prunus domestica*) trees growing in the University orchards at Davis, California. Samples were collected at intervals from January 5, 1928, to April 9, 1929. Each sample was divided into leaf, spur, bark, and wood fractions. Leaves were available for analyses only from March 11 to July 31, 1928. The same group of trees was used throughout the entire period of sampling.

The designations "bearing" and "non-bearing" as used in this report refer to the condition of the trees during the summer of 1928. Samples taken from trees that produced a crop during the summer of 1928 are referred to as "bearing" samples throughout the entire period of sampling even though these trees produced practically no blossoms and set only a few fruits in 1929. Similarly, samples taken from trees which produced practically no fruit during the summer of 1928 are designated "non-bearing" samples for the entire period of sampling. These trees, however, produced a heavy bloom and set a large crop in 1929. A discussion in greater detail is given by Davis (1) regarding the methods of sampling and the condition of the trees previous to and including the period of sampling.

The dried samples were ashed, using the conventional methods, and phosphorus was determined colorimetrically on the acid solutions, employing essentially the procedure outlined by Fiske and Subbarow (2).

The data as presented in Fig. 1 show that seasonal changes in the phosphorus content of the wood, bark, and spurs were similar. That is, the large amount of phosphorus during January and February of 1928 in samples taken from trees that would bear a crop that same year was characteristic of the wood, bark, and spur fractions. The minimum occurring in April for wood and bark and in May for the spurs continued with only slight variations until the end of August. An increase was noted in the bark and spurs from then on until March, 1929, when the phosphorus content was again at a maximum. The increase in the wood, however, did not occur until March, 1929, but here also the phosphorus content was at a maximum. The rapid decline in the amount of phosphorus previously noted in the early spring of 1928 was repeated during the corresponding period of 1929 with wood, bark, and spur fractions showing changes that were similar. The maximum phosphorus content in the late winter and early spring of 1929 was not as great as that occurring in the same period of the previous year.

Fractions of wood, bark, and spurs obtained from trees that would not bear fruit in the summer of 1928, in contrast to the samples de-

[1]The writer wishes to express his appreciation to Dr. L. D. Davis for suggestions and criticisms of the problem presented herein.

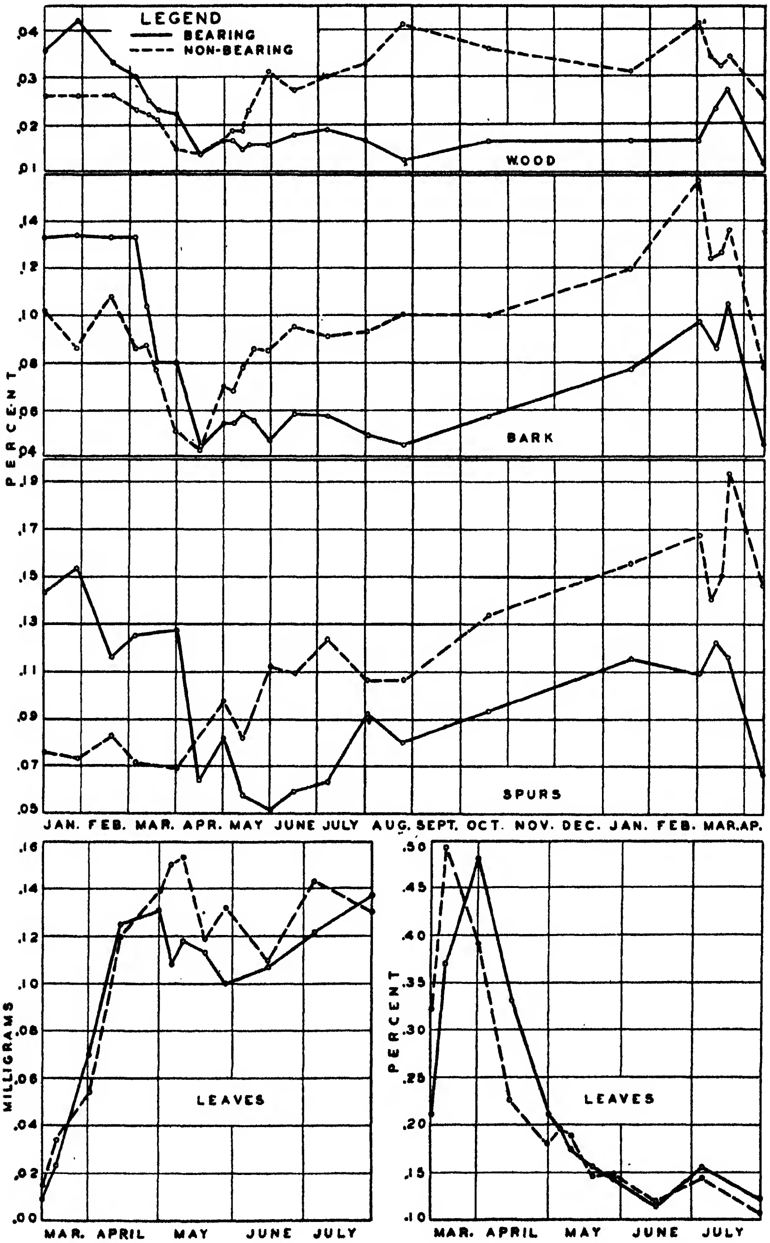

FIG. 1. The amounts of phosphorus as a percentage of the dry weight in the wood, bark, spurs, and leaves, and as milligrams per leaf, in alternate-bearing Sugar prunes.

scribed above, contained relatively small amounts of phosphorus during January and February. A minimum occurring in April in the wood and bark was of the same value as that previously mentioned for the same fractions taken from trees that would bear a crop during the following summer. The phosphorus content in the spurs showed no early spring minimum but remained practically constant from January to mid-April. Phosphorus in wood, bark, and spurs from trees not bearing a crop in 1928 increased rapidly and fairly uniformly from April to a maximum in March of the following year. Losses in March, 1929, were similar to those occurring at the same time in the previous year. However, the maximum of 1929 was much greater than in 1928. The above data indicate that the phosphorus content of the wood, bark, and spur fractions reflected the alternate-bearing condition of these Sugar prune trees.

Separation of bark and wood into two fractions is considered as a standard procedure in analytical studies such as that presented here. However, when the similarity in the data for wood and bark are considered, this separation would appear to be unnecessary for phosphorus determinations in the Sugar prune.

In contrast to the samples mentioned above, the leaves did not reflect the alternate-bearing habits of the trees. As shown in Fig. 1, phosphorus in absolute amounts increased rapidly during the first month following initiation of new shoot growth and then remained practically constant for the remainder of the sampling period with no significant differences between bearing and non-bearing material. On the other hand, following a rise during the first three weeks after initiation of new leaves, the phosphorus level decreased in relative amounts (Fig. 1) throughout the sampling period. Phosphorus apparently is not important as a storage constituent in leaves of the Sugar prune. The limited data suggest that leaves are of no value in demonstrating differences in phosphorus content between bearing and non-bearing Sugar prune trees.

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A Sweet Jonathan Bud "Sport"[1]

By LOWELL R. TUCKER, *University of Idaho, Moscow, Ida.*

THERE is an apple tree growing near Fruitland, Idaho, which resembles the Jonathan except that it produces a much sweeter fruit.

A number of trees were grafted in the spring of 1910 by J. F. Carnefix from scion wood collected from healthy Jonathan trees. The following November he sold a lot of at least 70 Jonathan trees from the nursery to J. K. Graham. In 1919 the fruit on one of these trees was discovered to be sweet. Mr. Carnefix stated in 1933 that, although he did not remember where he collected the scions, he does not know of any sweet Jonathan tree in the community of the age necessary to have furnished this wood. Though all the fruit on this tree is sweet, there was no other in the lot like it, indicating either that this is a bud sport or that of the scions collected only one was from this type of tree that itself was a sport.

Maturity and quality tests made on the apples from this tree and from a Jonathan tree nearby are shown in Table I.

These data show that this apple does not vary in diameter, weight, ground color, red color, firmness or soluble solids from the regular Jonathan any more than fruits from different trees of a variety normally vary. The tests show, however, that the regular Jonathan contains four to five times as much acid as this apple. The sweet strain contains even less acid than does Delicious at the same date. The texture of this apple seems to be identical with that of the Jonathan. No difference could be observed in leaf serrations or shape or in characteristics of tree growth between this tree and the Jonathans nearby.

The variety "Sweet and Sour" described by Whitney (3) and Beach (1) was noted for its production of both sweet and sour fruits on various limbs of the same tree. A recent summary of the literature on bud sports by Bregger (2) listed variations in color, size and productiveness but none in acid content.

Sweet Jonathan is the name suggested for this apple.

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[1]Published with approval of the Director as Research Paper No. 113 of the Idaho Agricultural Experiment Station.

TABLE I—MATURITY AND QUALITY TESTS OF JONATHAN AND A PRESUMED SWEET SPORT (FIGURES ARE AVERAGES OF 10 FRUITS, EXCEPT THAT 20 WERE USED IN THE CARNEFIX SAMPLE)

Variety	Date Tested	Average Diameter (Inches)	Average Weight (Gms.)	Average Ground Color (No.)	Average Red Color Per cent	Average Firmness (Lbs.)	Per cent Soluble Solids in Juice	Acid Normality
Sweet Jonathan	Oct. 2	2.7	116	3.75	79	15.3	14.3	.034
	Oct. 9	2.6	107	3.65	81	15.2	14.8	.036
Jonathan	Oct. 2	2.6	114	3.55	84	17.3	13.9	.167
	Oct. 9	2.6	115	3.70	90	16.6	13.9	.143
Jonathan (Carnefix orchard)	Oct. 9	2.7	122	3.70	97	16.7	14.5	.128
Delicious	Oct. 9	—	—	—	—	—	14.3	.052

A Comparative Study of the Intercellular Spaces of Apple Leaves[1]

By Wm. F. Pickett, *Kansas Agricultural Experiment Station, Manhattan, Kans.*

A NUMBER of factors are generally recognized as having influence on photosynthesis. These are the carbon dioxide supply of the atmosphere, the kind and intensity of light, temperature, amount of chlorophyll, moisture conditions, and protoplasmic factors. It is also considered that certain morphological features of leaves may influence the rate of photosynthesis. The purpose of this paper is to present the results of some studies on the internal structure of several varieties of apple leaves. No attempt is made in this article to correlate these studies with photosynthetic behavior, although that is the ultimate aim of the project of which this paper constitutes a preliminary report.

Methods and Materials

In August, 1932, and in June, 1933, fully grown leaves were collected from the outer periphery on the south sides of 20-year-old trees of each of the following apple varieties: Delicious, Gano, Jonathan, Liveland, Wealthy, Winesap, and York. A piece of tissue about 1 cm square was cut from each of these leaves and plunged immediately into a chromo-acetic acid solution containing 1 per cent acetic acid. These samples were washed, dehydrated, and cleared in the usual manner and embedded in paraffin. The use of butyl alcohol was found to give more satisfactory results than xylol in the infiltration of the paraffin into the leaf tissue. The sections were cut on a rotary microtome to a thickness of 10 microns and then were stained in Saffranin O rather heavily so that the projected images would be distinct.

To permit a study of the looseness or compactness of the mesophyll, the slides were mounted on a microscope so arranged that it served as a microprojector. A spot light was used as the source of light and the images from the projector were focused on a screen 43 inches from the outer end of the microscope barrel so that the leaf sections were magnified approximately 900 diameters. Fifty tracings of representative samples of the mesophyll of each variety were made on paper, not more than five tracings being made of sections from any one leaf.

To secure mathematical descriptions of the relative compactness of the mesophyll, the cross sectional areas of the intercellular spaces, as traced on the paper, were computed with a planimeter. By use of a chartometer the total linear perimeter measurement of each tracing was determined. Some of the data are presented in Table I, which presents only the data for the leaves sampled in 1933.

[1]Contribution No. 123. Department of Horticulture.

TABLE I—INTERCELLULAR MEASUREMENTS OF APPLE LEAF MESOPHYLL*

Variety	Average Cross Sectional Area of Intercellular Spaces (Sq. in.)	Average Perimeter Measurements of Intercellular Spaces (In.)
Delicious	8.80±0.79	58.31±5.07
Jonathan	9.48±1.34	62.52±6.07
Gano	10.43±1.19	60.80±4.51
Winesap	12.38±1.11	70.84±2.43
York	12.68±1.45	74.81±6.91
Wealthy	12.74±1.07	75.44±7.01
Liveland	17.73±0.82	100.20±6.88

*Measurements for each variety were made from 50 projected images, 11 inches long, at a magnification of x 900.

The differences between the measurements of the intercellular spaces in the mesophyll of some of these varieties are highly significant, statistically. Between others, however, the differences are not significant.

The differences between the means of the intercellular area measurements are presented in Table II and their perimeter differences in Table III. According to Table II, the differences between the cross sectional area measurements of Liveland and those of Delicious, Jonathan, Gano and Winesap are significant to the extent that the differences are at least four times their probable errors. The differences between the means of Liveland and the other varieties vary, in terms of their own probable errors, from 7.8 for the Liveland-Delicious comparison to 3.04 for the Liveland-York comparison.

The statistical significance of the differences between the means of the perimeter measurements of the intercellular spaces of these varieties is not as great as for the measurements of the cross sectional areas of the intercellular spaces. It is noteworthy, however, that these seven apple varieties have the same relative rank in the area measurements as in the perimeter measurements with the exception of Jonathan and Gano. Gano has the greater area of the intercellular spaces, but Jonathan has the greater perimeter measurements.

Stomatal behavior was studied on samples collected July 10, 1933 Strips of the lower epidermis of the leaves were taken by making a small cut under the epidermis, near the midrib, with a safety razor blade, after which an assistant quickly jerked with a pair of tweezers as much of the epidermis as would tear. The section secured by starting near the midrib and tearing the epidermis laterally toward the leaf margin, was triangular in outline because the epidermis tore along the smaller veins. The epidermal section was plunged immediately into absolute alcohol, the entire operation requiring only 2 or 3 seconds. Later the strips were stained in 1 per cent Gentian Violet or 1 per cent Saffranin O in absolute alcohol, rinsed in absolute alcohol, and permanently mounted in euparal. The preparation of permanent slides seemed necessary because considerable time was

TABLE II—Differences Between Means of Cross Sectional Area Measurements of Intercellular Spaces in Apple Leaf Mesophyll. (Sq. ins.)

Variety	Delicious	Jonathan	Gano	Winesap	York	Wealthy
Jonathan	0.68 ± 1.55	—	—	—	—	—
Gano	1.63 ± 1.42	0.95 ± 1.79	—	—	—	—
Winesap	3.58 ± 1.36	2.90 ± 1.73	1.95 ± 1.62	—	—	—
York	3.88 ± 1.64	3.20 ± 1.97	2.25 ± 1.87	0.30 ± 1.82	—	—
Wealthy	3.94 ± 1.33	3.36 ± 1.71	2.31 ± 1.60	0.36 ± 1.53	0.06 ± 1.80	—
Liveland	8.93 ± 1.14	8.25 ± 1.56	7.30 ± 1.44	5.35 ± 1.37	5.05 ± 1.66	4.99 ± 1.34

TABLE III—Differences Between Means of Perimeter Measurements of Intercellular Spaces in Apple Leaf Mesophyll. (Ins.)

Variety	Delicious	Jonathan	Gano	Winesap	York	Wealthy
Jonathan	4.21 ± 7.90	—	—	—	—	—
Gano	2.49 ± 6.78	1.72 ± 7.56	—	—	—	—
Winesap	12.53 ± 5.62	8.32 ± 6.53	10.04 ± 6.88	—	—	—
York	16.50 ± 8.57	12.29 ± 9.19	14.01 ± 8.31	3.97 ± 7.40	—	—
Wealthy	17.13 ± 8.65	12.92 ± 9.27	14.64 ± 8.33	4.60 ± 7.41	0.63 ± 9.89	—
Liveland	41.89 ± 8.54	37.68 ± 9.17	39.40 ± 8.22	29.36 ± 7.29	25.39 ± 9.75	24.76 ± 9.82

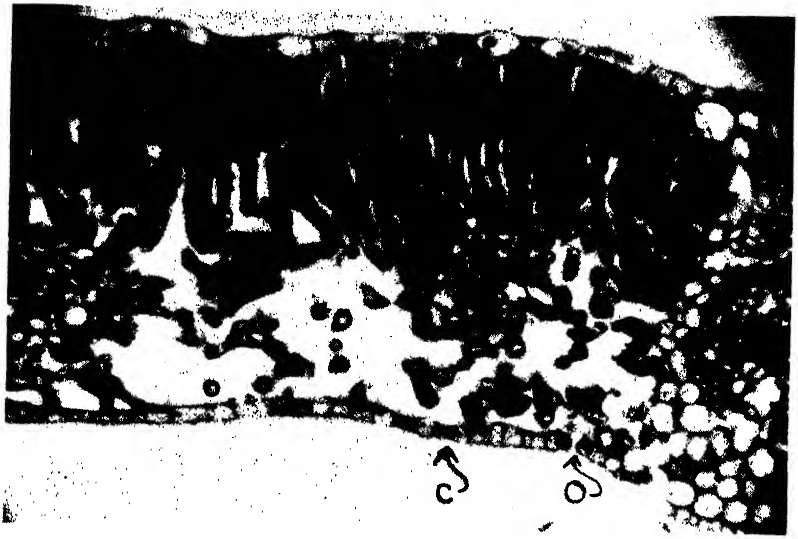

FIG. 1. Cross section (X 325) of Liveland apple leaf. Note open stoma at "O" and closed stoma at "C."

FIG. 2. Cross section (X 325) of Delicious apple leaf.

required to determine which stomata were open, due to the fact that, with the exception of Jonathan, the stomata were never more than partly open.

On July 10, the soil in which these trees were growing contained 20 per cent moisture and the day was clear and bright during all the day-light hours. The data are presented in Table IV.

TABLE IV—STOMATAL BEHAVIOR, JULY 10, 1933

	5:00 a. m	9:00 a. m.	1:00 p. m.	3:30 p. m.	7:00 p. m.
Temperature.......	75	84	90	93	89
Rel. humidity per cent.......... ..	96	76	65	57	52
Varieties			*Percentage stomata open*		
Delicious..........	20	10	0	1	1
Jonathan..........	10	96	0	0	0
Gano.............	55	23	2	1	1
Winesap...........	25	2	0	0	1
York..............	20	5	0	0	0
Wealthy...........	1	11	0	0	0
Liveland	11	4	0	0	0

In compiling Table IV no distinction was made between the stomata which were only partly open and those open to a greater degree—both conditions were listed as being "open."

Photomicrographs of typical cross sections of Liveland (Fig. 1) and Delicious (Fig. 2) leaves show much difference in the compactness of the mesophyll. In making these photographs a low power (4 mm) objective was used. After the photographs were made, a high power objective was used and part of the field shown in the photographs was projected on a screen as previously described. The area of the intercellular spaces for the Delicious was 9.09 square inches and for the Liveland 17.75 square inches.

Discussion

The observations recorded in Table IV and many others not presented in this paper indicate that stomata of apple leaves under Kansas conditions are open but little after 9 a. m. During the hot dry weather of June, 1933, the stomata were found to be closed or nearly so during the entire 24-hour period. On such days, however, the leaves gained in dry weight, as judged by the "leaf punch" method described by Miller, in Plant Physiology, page 474. Evidently the cuticular absorption of carbon dioxide is greater than generally assumed or some of the stomata judged to be closed were open sufficiently to permit the entrance of this gas.

The carbon dioxide that takes part in the phenomenon of photosynthesis enters, for the most part, through the stomata and diffuses through the intercellular spaces to the moist surfaces of the mesophyll where it is absorbed. There is a possibility, therefore, that

the superficial area of the intercellular boundaries may be a factor at least partly governing the rate of absorption of carbon dioxide and thus influencing the rate of photosynthesis. If this relation exists, it would be interdependent on other factors which condition photosynthesis, particularly stomatal behavior. Studies are now being made to determine whether comparison of the rates of photosynthesis between leaves of various varieties shows variations comparable with those found in the interstices of the mesophyll.

Preliminary Studies on the Internal Atmosphere of Apples

By Oscar J. Dowd,[1] *Experiment Station, Wooster, Ohio*

THIS paper briefly presents the results of one summer's study on the progressive changes taking place in the internal atmosphere of Rome Beauty apples during a part of the growing season. This study constituted one phase of another problem, and is presented before completion because conditions prevent further study at this time.

The progressive change in the internal atmosphere of pears and apples during storage has been studied by Harley (1), Harley and Fisher (2), and Magness and Ballard (4). Their findings emphasize the need for more study of the internal atmosphere of fruits in relation to certain storage disorders. Knowledge of the progressive changes in the internal atmosphere of growing fruit may constitute a background for these storage studies.

Rome Beauty apples, from the University of Maryland Agricultural Experiment Station orchard, College Park, Maryland, were picked and immediately brought to the laboratory. The internal gases were extracted from sections of the flesh of the apple taken with a cork borer as described by Magness (3). No sections were taken through the core. Gases extracted during the first 1-minute evacuation were discarded to avoid possibility of contamination of the gas sample. Gases collected during the second evacuation of 5 minutes were collected in glass vials over mercury. A small Syracuse watch-glass slipped under the open end of the glass vial while it was still in the mercury bath was found to provide a tight seal and thus prevent contamination of the gas sample which often occurs when corks are used for the same purpose. Analysis of the carbon dioxide and oxygen were made in a Bonnier-Mangin gas analysis apparatus.

The results of the analyses of the internal atmosphere of Rome Beauty apples at intervals during the growing season are presented in Table I.

The results obtained show that the percentage by volume of carbon dioxide tends to decrease during the growing period. The low percentage of carbon dioxide found on August 12 agrees with the findings of Harley and Fisher (2) who report that the intercellular gases of Jonathan apples at time of picking, September 13, contain an average of 3.8 per cent carbon dioxide. The progressive development of cuticle during the growing season reported by Markley and Sando (5) apparently does not progressively inhibit the escape of carbon dioxide formed within the fruit. The higher percentage of carbon dioxide found in the early stages of growth is undoubtedly due to a higher rate of respiration in young rapidly growing cells.

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TABLE I—CHANGES IN INTERNAL ATMOSPHERE OF ROME BEAUTY APPLES DURING GROWTH

Date 1933	Average Circumference (100 Fruits) (Cm.)	Number Fruits Analyzed	Average (Per cent)		Carbon Dioxide (Per cent)		Oxygen (Per cent)	
			CO_2	O_2	Maximum	Minimum	Maximum	Minimum
6/10	8.6	1	27.1	4.6	—	—	—	—
6/18	9.1	5	32.4	5.0	36.7	24.6	6.2	3.2
7/16	15.0	10	20.7	12.0*	24.6	13.4	17.5	8.0
7/23	16.1	9	21.5	8.8	24.8	16.2	11.6	7.5
7/30	17.2	9	14.9	12.3	19.3	11.5	14.0	9.0
8/5	17.7	7	9.1	15.7	13.4	9.6	16.4	14.7
8/12	18.3	12	3.7	19.1	5.1	2.4	22.6	17.8

*8 fruits analyzed.

The gradual increase in the percentage by volume of oxygen in the fruit during the growing season is probably due to a slower rate of respiration. The results obtained on August 5 and August 12 compare favorably with the percentage of oxygen found by Harley and Fisher (2) in Jonathan apples at time of picking.

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Spring and Mid-Summer Applications of Nitrogen in the Apple Orchard[1]

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IN most of New England, the prevailing system of orchard soil management is a sod culture in which the grass is cut and left lie. Liberal applications of some form of readily available nitrogen are made, generally early in the spring when growth is just starting. A few years ago, however, a number of growers in the vicinity of Wilton, N. H., began to divide the fertilizer, applying part in the early spring and the remainder in late June or early July. This practice had its inception in the belief that with a renewed supply of nitrogen in mid-summer, the rate of growth and ultimate size of the fruit would be improved. Although it was known that the supply of carbohydrate as determined by the leaf area and water supply is of major importance in determining the size of the apples, it was nevertheless logical to assume that adequate supplies of nitrogen are also essential to the growing fruits. Evidence that such is the case has since been published by Murneek (5) in 1928 and by Potter and others (8) in 1930. Since Lyon, Heinicke, and Wilson (6) had previously shown that in sod orchards heavy applications of available nitrates made in early spring, disappear from the soil by mid-season, it seemed possible or even probable that a mid-season application of nitrogen might be beneficial to fruit size. The experiment reported here was begun to determine whether such mid-summer applications of nitrogen produce an increase in the size of fruit which is measurable under field conditions.

Notwithstanding these rather promising hypothetical grounds for expecting the size of the apples to be benefited, it was possible by the close of the season of 1927 (7) on the basis of evidence from experiments which had been carried on for two or three seasons at Durham, and for one season in the Wilton district to prove that the size of the fruit had not been influenced. There seemed at that time, however, to be some slight evidence that the late application of nitrogen had improved the set of fruit in the following spring. Hence the experiment has been continued through the present season in order to determine as accurately as possible what tree functions, if any, are influenced by this practice.

The whole trend in modern field plot technique seems to be toward the use of a considerable number of small and closely adjacent plots. To quote Engledow and Yule (2), "small contiguous or closely adjacent plots tend to resemble each other.... [in comparing two treatments], the standard error may be reduced by increasing the number of pairs of such adjacent and comparable plots." In this experiment, the single tree was made the unit. For each tree on which the nitrogen applications were to be split, a control tree was selected, under as

[1]Scientific Contribution No. 42, New Hampshire Agricultural Experiment Station.

nearly identical conditions as possible. Since unfortunately no records of the yield or growth of these trees was available the selection was made on the basis of size, general appearance and location. Replicates were arranged at random. In fulfilling these conditions, it was not always possible to have the two trees as far apart as might be desirable. However, if the root distribution of these trees corresponds to those rather similar ones investigated by Beckenbach and Gourley (1), there was very little if any cross feeding. Even if some cross feeding took place, it is doubtless fair to assume that there was no cross transfer of the minerals, and if this is true, no large proportion of the bearing surface of the trees could have been affected in any case. At most, cross feeding might reduce but not eliminate any difference between the treatments.

In an orchard at Temple, 50 trees were thus selected and arranged in 25 pairs. There were 10 pairs of Baldwin trees about 40 years of age at the beginning of the experiment, 5 pairs of Rhode Island Greenings of about the same age as the Baldwins and 10 pairs of McIntosh which were 14 years old in 1927. The Baldwin and Greening trees each received 16 pounds of nitrate of soda annually and the McIntosh 8 pounds. From 1928 to 1933 inclusive, the percentage of spurs forming blossom buds and the per cent of blossoming spurs to set fruit were determined annually by examining 1,000 to 1,200 individual spurs on each of the mature trees and about 800 to 1,000 in the smaller McIntosh trees. These spurs were taken at random in about equal number from each of four sides of the tree. As examined, the spurs were counted in three different classes, namely, those which had failed to bloom, those which had bloomed but had not set fruit, and those which had bloomed and set fruit. From these data the percentages of fruit bud formation and set were calculated. At harvest time, 12 random samples of apples were taken from each of the large trees, one from the top, one from the middle, and one from the bottom of the fruiting area of each side, east, west, north, and south in the case of the mature trees. Eight samples were taken from the McIntosh, one high and one low from each side of the tree. These samples were weighed accurately and the number of fruits counted to determine the average weight or size of the apples. During the last two seasons eight or a dozen individual apples were taken from each of these samples except those of Rhode Island Greening and classified as to percentage of the surface covered with a characteristic shade of red. The balance of the crop was weighed as picked to determine the total yield per tree. At the end of the season, the increase in diameter of the trunks was measured and the length of annual twig growth determined on 20 shoots per tree. These data are presented herewith together with an estimate of their significance.

Since in this case the observations are on successive pairs of presumably similar trees, the part played by uncontrolled factors and accordingly the significance of any difference which may be found is best calculated by the use of Student's method or some modification of it. I have followed the arithmetical procedure as given by Fisher (3) in paragraph 24 of the fourth edition of his text. By this plan

TABLE I—EFFECT OF DIVIDING THE ANNUAL APPLICATION OF NITROGEN IN ORCHARDS UNDER SOD MULCH CULTURE

1	2	3	4	5	6
Criterion	Variety	Period	Average for Trees Receiving all Nitrogen in One Early Application	Gain or Loss Due to Dividing the Application	P. from* Fisher's table of "t"
Average annual yield (pounds per tree).	McIntosh	1928–33	198	+52	.2 to .1
	Rhode Island	1927–32	772	-126	.3 to .2
	Baldwin	1928–33	398	+8	.8 to .7
Average size of apple (weight in ounces).	McIntosh	1927–33	3.53	0.00	—
	Rhode Island	1927–32	3.62	-0.18	.2 to .1
	Baldwin	1927–33	3.70	+0.17	.3 to .2
Average color (per cent of surface colored).	McIntosh	1932–33	72	0	—
	Rhode Island				
	Baldwin	1932–33	48	+1	.8 to .7
Per cent of spurs forming blossom buds.	McIntosh	1928–33	71	+3	.2
	Rhode Island	1928–33	55	-5	.4
	Baldwin	1928–33	43	+2	.2 to .1
Per cent of blossoming spurs setting fruit.	McIntosh	1928–33	32	+4	.2 to .1
	Rhode Island	1928–33	47	+4	.6 to .5
	Baldwin	1928–33	53	+5	.2
Average annual twig growth (inches).	McIntosh	1927–32	7.6	+0.5	.2 to .1
	Rhode Island	1927–32	5.4	-0.2	.9 to .8
	Baldwin	1927–32	5.3	0.0	—
Increase in trunk diameter (inches).	McIntosh	1927–33	2.4	+0.3	.2 to .1
	Rhode Island	1927–33	1.6	-0.5	.1
	Baldwin	1927–33	1.6	+0.2	.4 to .3

*A value for P of 0.05 or lower would denote a significant gain or loss.

one calculates in succession the difference between the two trees in each pair, the average of these differences for the series, and the standard error of this average. Dividing the average difference by its standard error gives the statistic which Fisher designates by the use of the the letter "t." By reference to Fisher's table, the probability is then found of the two samples compared being merely successive random samples from the same population. This probability expressed in decimal form is given in column 6 of the table. Thus the color of Baldwins from the trees on which the nitrogen application was divided was found to be 1 per cent greater than that of Baldwins from the trees receiving all of the nitrogen in one application in early spring, but it is indicated in column 6 that, in 7 or 8 cases out of 10, variations

as large as this would occur in taking two successive samples from the same plot.

The data indicates perhaps more forcefully than anything else the difficulty of avoiding comparatively large errors due to uncontrolled factors when working with trees under field conditions. Thus in the case of the McIntosh, an increase in yield of 52 pounds per tree which is about 25 per cent of the average annual yield of the control trees, is supported by odds too low to give it statistical significance. The fact that in the case of the Baldwins the increase amounts to only 2 per cent of the average yield of the control trees and that in the case of the Rhode Island there is actually a decrease of about 12 per cent would indicate that all yield differences are merely chance fluctuations. In no instance is there adequate evidence that dividing the application of nitrogen has actually altered the growth or functioning of the tree. Apparently, if the level of nitrogen metabolism is satisfactorily maintained, it makes no difference whether the supply is replenished once or twice each year. Since it remains true that nitrogen is needed for fruit development and that it is unlikely that the roots of trees under sod culture are able to absorb any large amount from the soil in late summer, these findings may in some measure substantiate much other evidence which might be cited to prove that nitrogen may be stored and moved within the tissues of the tree as needed for successive functions. It may be worth while to add further that after this experiment had been in progress for 3 or 4 years, growers in this district ceased to divide the application of nitrogen.

These results do not seem to agree with those of HofMann (4) who reported an average increase of 86 pounds per tree from splitting the nitrogen application on the York variety in Virginia. Whether or not this is a significant increase depends on the arrangement of the plots. Neither "Students" formula nor the method used in this paper can be appropriately applied to his data if for instance all of the plots having a given treatment are side by side. Then too, the response of York under the climatic conditions of Virginia might well differ from that of Baldwin and McIntosh in New England.

These data may have some interest aside from the question of dates or methods of nitrogen application. I know of no other case in which data not only on growth but also on percentage blossom formation, percentage set, and average size of apple may be correlated with yield. The number of new fruit spurs formed would in the long run be pretty closely proportional to the length of annual twig growth. Referring to column 5 of the table, it may be seen that the increased yield of McIntosh trees with divided applications is readily explained on the basis of slightly more new spurs, greater fruit bud formation and better set than the controls. In the case of the Baldwin increased production may be anticipated because of slightly better blossom formation and set together with larger fruit size. The Rhode Island trees, however, had less new spurs, lower blossom bud formation and smaller apples which would tend to decrease total weight of crop in spite of a somewhat better set. These observations should not

befog the main issue and conclusion of this paper. While these actual differences were found and are apparently correlated with the total yields obtained, they are more likely due to unknown factors than to the methods of applying nitrogen. It is possible, of course, that the difference in time of applying a part of the nitrogen has actually altered the functions of the tree but to an extent too small to be determined under the conditions of this experiment.

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Effects of Temperature on the Growth and Composition of Stayman and Baldwin Apple Trees

By M. A. Blake, *N. J. Agricultural Experiment Station, New Brunswick, N. J.*

Abstract

This material will be published as a bulletin by the New Jersey Agricultural Experiment Station.

Carbon Dioxide Assimilation by Apple Leaves as Affected by Lime-Sulphur Sprays. II: Field Experiments

By M. B. Hoffman, *Cornell University, Ithaca, N. Y.*

IT has been shown previously that lime-sulphur sprays may appreciably decrease the rate of carbon dioxide assimilation by apple leaves without the appearance of visible injury (4). All of the results reported in this first paper were obtained while working with 1-year-old McIntosh whips under greenhouse conditions. During the summer of 1933 similar studies have been made in the orchard of Cornell University at Ithaca, N. Y.

The method used in the greenhouse studies for determining the amount of carbon dioxide assimilated by the leaves has been described in detail (3). This method is well adapted for orchard work when some sort of a movable shelter is provided to protect the apparatus from extremes in weather conditions. Suction flasks containing the absorbing agent are prepared in the laboratory and transported to the field where they are connected to the absorption towers of the machine without exposure to the atmosphere. At the end of the run they are again returned to the laboratory for titration. The cellophane envelope has been found to be a convenient leaf chamber for this work.

The materials used in these studies were vigorous 6-year-old trees which were growing in grass or alfalfa sod, with and without added nitrogen. Northern Spy, Cortland, and McIntosh were the varieties used. Leaves to be worked with were usually selected on the east or southeast side of the tree, about 4 to 5 feet from the ground. Such a position was always well exposed to the light throughout the determinations. The leaves used were of average size, occurring about the middle of a 1933 terminal shoot, although some determinations have been made on spur leaves.

As Heinicke (2) has pointed out, two similar apple leaves growing on the same shoot may vary appreciably in their activity, even though the environmental conditions are the same. There are, of course, daily variations of the individual leaf caused by changes in weather and other factors, but ordinarily the relationship of one leaf to another holds from day to day. For this reason, the rate of carbon dioxide assimilation for individual leaves was determined for several days before any treatment was given. When the relationship of the separate leaves to one another was thus established, some of the leaves were sprayed and the remainder were left untreated as checks. The assimilation rates of these leaves were then studied for several days. All determinations started about 8:30 a. m. and lasted for 5 hours.

Unless otherwise stated, the spray material used in the experiments reported here was the regular summer strength lime-sulphur (2½ gallons of commercial lime-sulphur in 100 gallons of water). A small

atomizer has been used in making the application and the leaf was sprayed so as to wet completely both surfaces.

Results

In general, the earlier results obtained in the greenhouse have been confirmed in the orchard. Table I shows the reduction in leaf efficiency caused by an application of lime-sulphur made under the conditions of this experiment.

In the left-hand column of this table the leaf numbers are merely arbitrary numbers assigned to the leaves at the start of an experiment for the convenience of orderly records. Leaves 1 and 2 were Cortland, while 3 and 4 were Northern Spy. Both trees were growing in alfalfa sod. They were vigorous and the foliage was dark green. The data in the second column are an indication of the efficiency of these leaves under the environmental conditions on that day. These data are expressed as the milligrams of CO_2 assimilated per hour per 100 square centimeters of leaf surface, and they show the relationship of one leaf to another. Determinations were made on these leaves for several days before any treatment was given. The results on July 12 were selected as typical.

At 3 p. m., July 12, leaves 1 and 3 were sprayed with lime-sulphur. Assimilation rates were then studied each day for the week following and the remaining columns give the results. The values of each leaf in the trial run preceding treatment are taken as 100. In the determinations following treatment, any deviation from 100 by the untreated leaves was regarded as due to changes in weather or other factors that affect assimilation; while in the case of the sprayed leaves, a deviation would include the treatment as well as a change in other factors.

From the standpoint of photosynthesis, this is regarded as a very uniform set of leaves before treatment. Leaves 1 and 3 were sprayed on a sunny afternoon when the temperature was 29 degrees C. The following day leaf 1 was reduced 41 per cent in its efficiency, while leaf 2, untreated, on an adjoining shoot of the same tree deviated only 5 per cent from its value of the preceding day. Although the greatest reduction in assimilation that might be attributed to spraying leaf 1 occurs the first day after treatment, this reduction continued in an appreciable and consistent amount for 7 days when the experiment was discontinued. Practically the same results were obtained with the two Spy leaves 3 and 4. There seems to be a little greater reduction with the Spy than with the Cortland, but one would not be justified in concluding that Spy is more susceptible to this injury than Cortland on the basis of this one experiment. Throughout the course of this experiment no marginal leaf burn, which is so characteristic of visible lime-sulphur injury, developed on the sprayed leaves. This is rather remarkable in view of the fact that every day was sunny and the temperature usually reached a maximum of 29 to 30 degrees C.

Not all of the orchard experiments have given so consistent and conclusive results as the one reported above. Data have been ob-

TABLE I—EFFECTS OF 1-40 LIME-SULPHUR ON CO_2 ASSIMILATION BY APPLE LEAVES

Leaf Number	CO_2 Assimilated Mg Hr 100 Cm^2	Treatment	CO_2 Mg Hr 100 Cm^2 Expressed in Per cent of Assimilation Before Treatment					
	July 12, 1933	3 p.m. July 12	July 13	July 14	July 15	July 17	July 18	July 19
1.	11.0	Sp. L–S	59.0	79.0	96.3	80.9	85.4	118.1
2.	10.0	Untreated	95.0	100.0	129.0	104.0	112.0	146.0
3.	13.8	Sp. L–S	50.7	63.7	82.6	78.2	68.8	107.9
4.	10.8	Untreated	90.7	98.1	112.9	128.7	109.2	163.8
Temperature (Degrees C)								
Maximum	30	—	30	29	28	28	29	32
Minimum	21	—	22	22	18	21	24	23
Weather								
	Sun	—	Sun	Sun	Int. Sun	Sun	Int. Sun	Sun
Light Intensity (foot candles)								
	9,400	—	9,200	10,000	10,000	10,000	8,900	9,900

tained on several series of leaves where no injury whatsoever could be attributed to a lime-sulphur spray, while in other cases very much more serious injury than is shown by Table I has been obtained with this spray. The more severe cases of reduced efficiency are usually accompanied by serious marginal burning 2 or 3 days after spraying, although the reduction in CO_2 assimilation shows up the first day after the application.

In studying the data of two experiments where no injury had resulted from spray, it was noticed that the applications of spray had been unintentionally made in the late afternoon about 6:30 to 7:00 p. m. While in all other cases where injury was obvious the spray had been applied during the early afternoon about 2:00 or 3:00 p. m. In view of these observations, a series of McIntosh leaves was tested for the purpose of spraying some of them during the early and others during the late afternoon. Two trees were used in this experiment. They were both under the same cultural treatment and of equal vigor. Leaves 1 to 4 were attached to one tree and leaves 5 to 8 to the other. Table II gives the results of this experiment.

TABLE II—COMPARISON OF 1-40 LIME-SULPHUR APPLIED AT DIFFERENT TIMES OF DAY ON CO_2 ASSIMILATION BY APPLE LEAVES

Leaf	CO_2 Assimilated Mg Hr 100 Cm^2	Treatment	CO_2 Mg Hr 100 Cm^2 Expressed in per cent of Assimilation Before Treatment			
	Aug. 14, 1933	Aug. 14	Aug.15	Aug.16	Aug.17	Aug.17*
1.....	12.3	Untreated •	104.8	96.7	104.8	—
2.....	12.0	Sp. L–S, 1:40 PM	26.6	19.1	11.6	15.8
3.....	13.9	Sp. L–S, 6:45 PM	70.5	73.3	73.3	—
4.....	9.5	Sp. L–S, 1:40 PM	40.0	37.8	36.8	37.8
5.....	9.8	Untreated	114.2	105.1	116.3	—
6.....	13.2	Sp. L–S, 6:45 PM	85.6	56.8	53.0	—
7.....	11.6	Sp. L–S, 1:40 PM	11.2	10.3	25.8	55.1
8.....	15.9	Sp. L–S, 6:45 PM	79.8	61.6	61.0	—
		Temperature (Degrees C)				
Min.	17	At 1:40—21.5	19	22	17	—
Max.	24	At 6:45—16	29	30	27	—
		Weather				
	Clear	Clear	Clear	Clear	Slightly cloudy	

*Correction for area showing spray burn.

After the test period on August 14, leaves 2, 4, and 7 were sprayed with lime-sulphur at 1:40 p. m. Leaves 3, 6, and 8 were sprayed the same day at 6:45 p. m. During the 3 days following treatment, all of the six sprayed leaves showed a reduction in efficiency. However, these treated leaves can be separated into two groups based on the rate of CO_2 assimilation and it is immediately apparent that the group sprayed at 1:40 p. m. (leaves 2, 4 and 7) shows a greater reduction

in efficiency than the group sprayed at 6:45 p. m. The performance of the untreated leaves is considered fairly constant throughout.

On August 16, some marginal burn developed on leaves 2, 4, and 7, but, it is interesting to note, this never happened to the leaves sprayed at 6:45 p. m. After the run on August 17, leaves 2, 4, and 7 were collected and the area showing marginal burn was measured with a planimeter. The amount of dead area was substracted from the original area and a similar calculation, which involved only the normal appearing tissue, was made for the run of August 17. The calculation is shown in the last column of Table II. This correction, with the exception of leaf 7, does not change the order of these leaves. Leaf 7 developed a larger area of burnt tissue than leaves 2 and 4 and hence showed a greater increase in efficiency when this discolored area was ruled out.

Data from other experiments indicate that greater differences than these might result from a comparison of mid-day and evening spraying; while in other cases, although the injury was severe, no difference could be attributed to the time of application.

In interpreting the results in Table II, attention is called to the temperatures that existed at the time the spray was applied. The temperature was 21.5 degrees C at 1:40 p. m. and 16 degrees C at 6:45 p. m. The day was clear and conditions for rapid drying were good at both periods. The higher temperature at 1:40 p. m., in the case of this experiment, was undoubtedly responsible for the greater reduction in assimilation by the leaves sprayed at mid-day. High temperatures are usually considered the most potent of environmental factors associated with lime-sulphur injury; however, too much emphasis should not be placed on the temperature factor alone. Spray applications made during October, 1933, when temperatures of 12 to 14 degrees C prevailed, have caused a rather serious reduction in assimilation. Dutton (1) reports severe leaf burn following an application of summer strength lime-sulphur (2½ gallons to 100) which was made while the temperature ranged from 37 to 40 degrees F (2.8 to 4.4 degrees C). The day was cloudy with some precipitation in the form of light rain and sleet and the spray dried very slowly.

Considerable effort is constantly being made to develop a slightly soluble sulphur spray of high fungicidal value. Several such commercial products are now offered for sale. New Jersey dry-mix has been taken as an example of this type of material and its effect on the rate of assimilation compared with that of lime-sulphur. After studying the rates of assimilation of six Northern Spy leaves, two were sprayed with dry-mix, two with lime-sulphur, and the other two left untreated. Table III gives the results of this experiment.

Leaves 1, 2, and 3 were attached to a nitrated tree, while leaves 4, 5, and 6 were on a non-nitrated tree. In examining the results after treatment, it is best to compare the nitrated untreated leaf with the nitrated sprayed leaves.

The spray was applied at 6 p. m. and a hard rain occurred about 1 hour later. On August 2 there is indication of a slight reduction in leaf efficiency due to lime-sulphur, but no injury can be attributed to

the dry-mix. August 3, was a very cloudy, rainy day. The weather conditions would have obscured any differences in assimilation caused by the sprays. There is no evidence of reduced assimilation by any of the sprayed leaves on August 4. The yield of leaf 3 was abnormally high on that day. This often happens to individual leaves on a clear day following a cloudy, rainy day. Since neither of the sprays applied at 6 p. m. August 1, had significantly reduced leaf efficiency, the treatments were duplicated on August 4, at 1:30 p. m. The temperature was 24 degrees C and the afternoon was clear.

TABLE III—COMPARISON OF 1–40 LIME-SULPHUR AND DRY-MIX ON CO_2 ASSIMILATION BY APPLE LEAVES

Leaf No.	CO_2 Assimilated Mg Hr 100 Cm^2	Treatment	CO_2 Mg Hr 100 Cm^2 Expressed in Per cent of Assimilation Before Treatment				
	Aug. 1, 1933	6p.m., Aug. 1	Aug. 2	Aug. 3	Aug. 4	Aug. 4	Aug. 5
1	10.8 N	Sp. Dry mix	134.2	54.6	142.5	Treatment of Aug. 1 duplicated today at 1-30 p. m., Temperature 24 C, Clear.	114.8
2	15.8 N	Sp. L–S	104.4	51.8	119.6		16.4
3	14.9 N	Untreated	142.2	50.3	173.1		121.4
4	9.9	Sp. L–S	84.8	43.4	108.0		31.3
5	17.1	Sp. Dry mix	102.3	52.0	99.4		76.6
6	15.1	Untreated	106.6	19.2	98.6		103.3
		Temperature (Degrees C)					
Min.	30		23	14	20		19
Max.	36		27	18	27		29
		Weather					
	Clear	Cloudy rain	Clear	Cloudy rain	Clear		Clear

On August 5 the amount of CO_2 removed from the air stream by the lime-sulphur sprayed leaves, 2 and 4, was much reduced. The decrease was 16.4 and 31.3 per cent, respectively, of the former values. Dry-mix seems to have caused a slight reduction in efficiency to leaf 5 on the non-nitrated tree, but no harmful effect can be attributed to this spray in the case of leaf 1. The data lend support to the determinations presented in Table II and suggest a difference in the effects of lime-sulphur and dry-mix on the photosynthetic process.

ACKNOWLEDGMENT

The help and advice of Dr. A. J. Heinicke, under whose general direction these studies were carried out, is much appreciated.

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Relation of Chemical Composition to Photoperiodic Effects in Plants

By A E. MURNEEK, *University of Missouri, Columbia, Mo.*

ABSTRACT

This paper will be published in full elsewhere.

PLANTS (mainly soybeans) were submitted to a short (7 hour) day and a long (14 hour) day to initiate and maintain either reproductive or vegetative development. Reproductive plants were higher in carotin, xanthophyll and probably vitamin A content, had an increased dry weight, a higher concentration of nitrogen compounds and a greater accumulation of carbohydrates (primarily starch). The largest amounts of practically all determined forms of nitrogen (protein, proteose, basic, ammonia, amide, humin, amino and nitrate) were found in the stems, especially nodes, of short-day (reproductive) plants. All stems exhibited, from the base to the top, an ascending gradient of protein, humin, ammonia and proteose nitrogen and a descending gradient of nitrate nitrogen. A conspicuously low concentration of nitrate-N was found in tips of stems of long-day (vegetative) plants. The bearing of these records on the metabolism and behavior of reproductive and vegetative plants and on the carbohydrate-nitrogen relationship concept will be discussed.

A Seven-Years' Study of the Fruit Bud Level in Elberta

By R. L. McMunn and M. J. Dorsey, *University of Illinois, Urbana, Ill.*

IN the spring of 1925 a fertilizer experiment was started with 3-year-old Elberta peach trees in the L. S. Foote orchard in Johnson County, Ill. The experiment was initiated to determine, among other things, the set of fruit buds from plots receiving varying amounts of fertilizer, applied at different times during the spring and summer. Data on the fruit bud set were taken over the 7-year period of the experiment and in addition, observations with a few bud counts were made for 2 years after the experiment was discontinued. Aside from differences in the fertilizer applications, all plots were given the same cultural treatments, spray applications, and pruning, and each crop year the fruit was thinned to about a 6-inch spacing.

Each spring from 1926 to 1932 inclusive, ten unbranched terminal shoots, located 5 to 8 feet from the ground and spaced at fairly regular distances about the top, were collected from each of the inside trees of the different plots. As the experiment was laid out, a total of 219 trees was included in the twig collections from the 16 different plots. The 10 shoots from each tree were selected as representative of the average length of the unbranched, outside terminals. Because of the fact that growths of this type in the peach are so directly influenced by all growth factors, the study was based upon them rather than shorter spur growths or a random sample. Since the collections included from 140 to 200 shoots per plot (except the two check plots, 40 to 80 shoots) the data appear to represent fairly accurately the fruit bud level of the different treatments or seasons. This would seem to be especially true in view of the large number of nodes involved in the study. When the fruit bud counts were made, each shoot was divided into three sections of equal length. The nodes and fruit buds on each section were counted and from these records, the average number of fruit buds per node for each of the three sections of the shoot was calculated. The trend of the accumulated data for the sixteen plots is shown in Fig. 1, the fruit bud level being expressed as so many fruit buds per one hundred nodes.

From the data it will be seen that there was a low fruit bud level, for the shoots as a whole, in 1926, 1928, 1930 and 1932, and a high fruit bud level in 1927, 1929, 1931, and 1933. In years of a low fruit bud level more fruit buds were formed in the middle section of the shoot than on the base or terminal sections. In years of a high fruit bud level the greatest number of fruit buds were developed on the basal division of the shoot with fewer on the middle. The terminal section, on the other hand, bore less than half as many fruit buds as the basal one-third. This order of the fruit bud level was well marked in all of the plots and with individual trees during the first 4 years of the experiment. After the fourth year, in years of a low fruit bud level, a few trees showed some irregularity in fruit bud

production and tended to form more fruit buds on the basal section of the shoot than on the middle section, while in years of a high fruit bud level, some trees formed more fruit buds on the middle section than on the basal or terminal sections.

It will be evident to anyone who is familiar with peach culture that many things may affect shoot growth or fruit bud formation. It will be of interest, therefore, to note whether some of the more obvious factors which are so generally looked upon as having a direct influence upon growth, will be found to be associated or correlated with the fruit bud level.

From the data, it is apparent that the fruit bud level for the shoots, as a whole, has alternated regardless of the crop being produced, while the fruit buds were being formed, Fig. 1. If a high fruit bud level is reached in years of a light crop or a crop failure, there should have been a high fruit bud level in 1926 and in 1928, since the fruit buds counted in those years were formed the preceding summer. Actually, however, there was no fruit in 1925 and only a light crop in 1927. It is interesting to note that the 1932 fruit bud level was higher than that of 1928, even though the 1932 fruit buds were formed while the heaviest crop the orchard has borne, that of 1931, was on the trees. It will be noted, also, that the fruit buds for 1928 were developed during the light crop year of 1927. The fruit buds counted in the high fruit bud years 1927, 1929, 1931 and 1933, were produced when there was no crop in 1930 and 1932, or a light crop in 1926 and 1928. A high fruit bud level, therefore, cannot be correlated with fruit production, since that would call for a high fruit bud level in 1926 and 1928.

Of interest also, is the fact that the fruit bud numbers on the base, middle and terminal sections of the shoot have alternated each year with the alternation of the fruit bud level. It will be noted that the fruit bud level for 1934, a year when a low fruit bud set would be expected was about the same as for the high fruit bud years, 1929 and 1931, but was below that of 1927 and 1933. In 1934, when the fruit bud level was higher than average, the percentage of fruit buds on the middle third of the shoot was greater than on the base or terminal thirds. The fruit bud level of 1934 possibly would average somewhat lower, if more shoots had been available in securing the data. The shoots which were sent in may have been those carrying the greatest number of fruit buds, at least that seemed to be the case from the general characteristics of the type of shoots which were received. If such were the case the 1934 level is probably higher than the average of the plots as a whole, Fig. 1.

The data do not show that the amount or the time of the application of fertilizers had much influence upon the fruit bud level in the different plots. The check plots and all plots receiving fertilizers, whether applied early, or late in the season, as single or split applications and in amounts ranging up to 8 pounds per tree, showed a similar seasonal variation in the fruit bud level. While the trees in some plots formed fewer fruit buds than in others, the high and low levels in the different years were well marked.

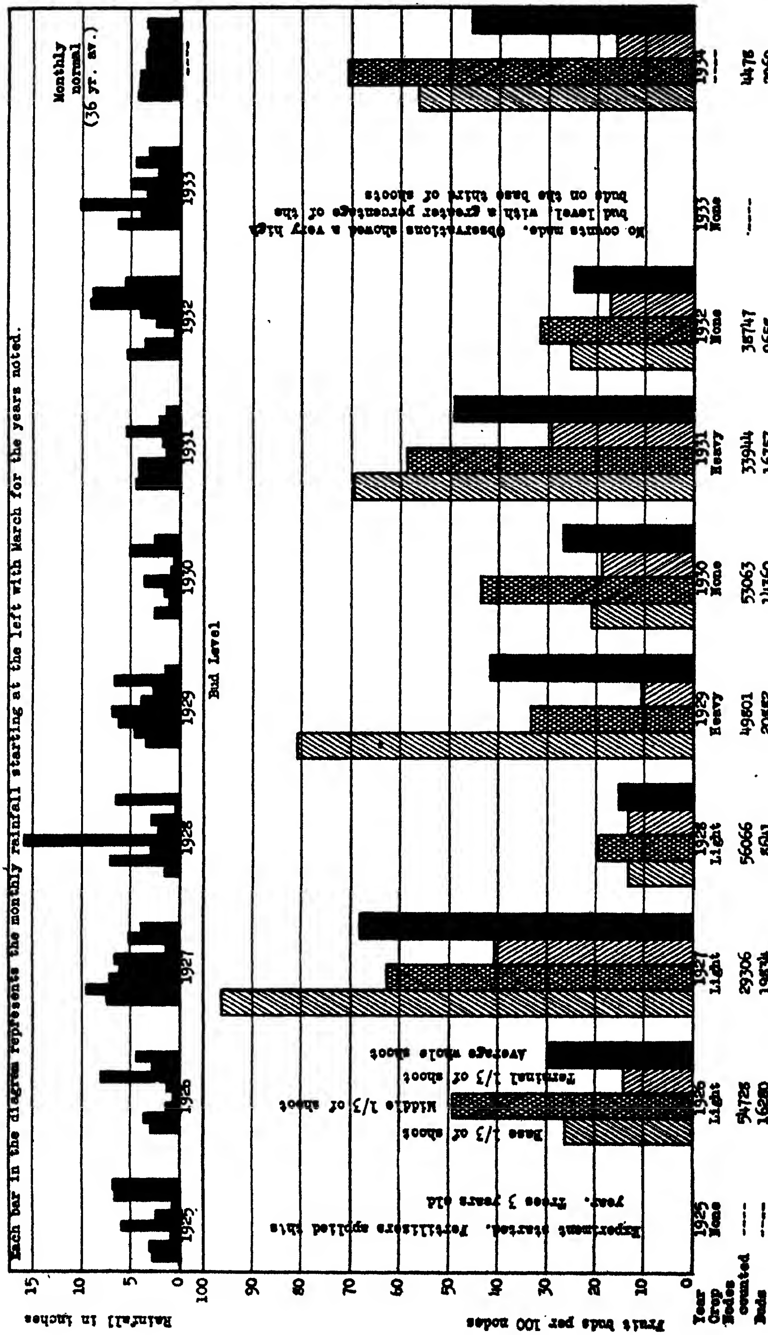

FIG. 1. Showing the bud level in Elberta, the crop produced, and the monthly rainfall for March to October, inclusive.

By referring to the rainfall record presented at the top of Fig. 1, it will be seen that, as with the other factors, the variations found cannot be correlated with either the monthly or the total rainfall during the growing season. In view of the great extremes in rainfall, however, the soil moisture, either as an excess or a deficiency, might be expected to have an important bearing upon the condition found.

It should be stated also, that defoliation from bacterial infection or drought was not severe during the time the experiment was being conducted. The defoliation that did take place came late in the season after the terminal buds on all but the longer shoots had been formed. Defoliation, therefore, cannot be considered an important factor in the alternation of the fruit bud level in this instance.

It will be readily admitted that the above analysis of some of the more obvious factors which may affect growth and fruit bud formation are only suggestive. Many other factors might be mentioned but none of them was given special attention. It is worthy of note, however, from the results of this experiment, that, where the fruit bud level is used as a measure of the effectiveness of a treatment or of a condition, it may normally be expected to vary from year to year (1, 2) because of the combined influence of all growth factors during the time of fruit bud initiation.

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Influence of the Rest Period on Opening of Buds of Fruit Trees in Spring and on Development of Flower Buds of Peach Trees

By W. H. Chandler and W. P. Tufts, *University of California, Berkeley, Calif.*

In southern Missouri, at latitude 36°30′, altitude about 950 feet, Elberta peach trees that, in the spring of 1910, had been pruned (dehorned) severely enough, or fertilized with nitrogen enough, to cause the growth of shoots 3 to 4 feet long, were not in full blossom by March 20, 1911, though trees that made only the normal, rather weak growth characteristic of lightly pruned, unfertilized trees in that orchard were nearly in full blossom a month earlier, on February 22 (cooler weather that intervened was responsible for part of this delay in opening of buds on trees that had grown late). This and other similar observations were presented (1) as evidence that when trees continue growth late and hold their leaves late in autumn or into early winter, it takes more chilling weather to break the rest of their buds. Likewise, Cooper and Wiggans (2) working in Arkansas at latitude 36°, altitude about 1450 feet, found, in some springs, blossoming several days earlier on trees that had made short growth in the preceding year than on trees that had made rather strikingly longer growth. The trees observed in Missouri had not borne in the preceding year, and those observed by Cooper and Wiggans had not borne in the year preceding one of the two crops. It is not probable that on trees bearing a fairly good crop, application of nitrogen could have induced such late growth or affected the blossoming time so much.

Crane (3), working in West Virginia, at latitude 39°30′, altitude about 430 feet, did not find application of nitrogen and the consequent later growth to delay blooming in the following spring. At latitude 39° in Missouri, during the years 1903 to 1913, blossoming was never delayed appreciably even on trees induced to make excessively long shoots in the preceding season.

Evidence that in Warm Climates Buds on Strong, Late-Growing Shoots Open Later than Buds on Weak Shoots Because on the Strong Shoots the Rest Is Not So Completely Broken

In the southern part of California, and in northern parts near the coast, after any of the warmer winters, there is abundant evidence that long, late-growing shoots do not have the rest well broken by amounts of chilling weather that cause starting moderately early in spring on short shoots that ceased growth early in summer.

Near Los Angeles, late in June, 1926, on peach trees, of an early variety, that had been pruned severely in the winter of 1924–25 the blossoms were just opening on the long suckers of 1925 when the

fruit was highly colored, and nearly ripe on growths of 1925 that were less than a foot long. Nearly as striking delays in starting of shoots that grew late in the preceding summer, on peach trees and on other deciduous kinds, could be seen in many orchards that year, and to a less extent in 1924, 1928, 1930, and 1931, all following warm winters.

Later starting on long growths can often be observed in Berkeley, California, a coastal position, where the time of opening of leaf and fruit buds is determined less by the spring temperature than by the amount of winter chilling weather; in fact the temperature is rarely too low in winter for opening of buds. For example, on October 1, 1930, two Early McIntosh apple trees were dug, each with a ball of earth about 12 inches in diameter and 18 inches deep, planted in garbage cans, and placed in storage at —1 to 0 degrees C, the leaves having first been cut off. These trees were removed from storage and planted in the orchard by the side of an undisturbed Early McIntosh tree, one on December 23, 1930, and the other on January 26, 1931. The results were:

	Leaves 1 cm Long	Leaves 2.4 cm Long	All Flowers Open
Tree taken from storage Dec. 23	Jan. 20	Feb. 2	Feb. 25
Tree taken from storage Jan. 26	Feb. 11	Feb. 18	Mar. 6
Tree left in orchard	Mar. 6	Mar. 13	Apr. 2

During this, an average winter in Berkeley, there was little, if any, weather too cold for opening of the buds; blossoming and beginning of growth were determined in each bud by the time when its rest was broken enough to permit response to favorable growing temperature. Following the warm winter of 1929–30, some long, 1929-shoots on young Northern Spy apple trees had no buds open until July 18, 1930, though shorter shoots on the same trees started before June 1 and shoots on older, weaker trees, before May 1. Blossoming was delayed until July 22, 1930, for 1929 buds on long shoots of a Red Canada apple tree, and until September, 1930, on long, 1929 shoots of a Cox Orange apple tree; on both, shorter shoots blossomed much earlier.

Hundreds of other similar observations could be cited of much delayed 1930 blossoming or starting from long, late-growing shoots of 1929. Peaches and nectarines showed the same phenomenon, but to a less extent than apples or some pears. In 1931, after a cooler but moderate winter, many long 1930 shoots of Northern Spy apple had started no growth by May 14, though the shorter shoots were growing earlier. A Northern Spy tree that was taken up and kept at 0 degrees C from March 9 to April 9, when it was returned to the orchard, had every terminal bud open by May 14, even on shoots 37 to 47 inches long, and many more lateral buds growing than on adjacent trees that had not had this additional chilling. In 1932, following a considerably colder winter (mean temperature December, January, and February, 9.2 degrees C, as compared with 11.0 degrees

C in 1930–31 and 11.4 degrees C in 1929–30), there was little difference in time of starting between long and short shoots. In other words, when the winter temperature is favorable for nearly complete breaking of the rest, or when storage temperatures are used to break the rest, the delay in starting of buds on long twigs, as compared with short twigs and spurs, tends to disappear.

It should be emphasized, however, that the differences cited for California, as well as for southern Missouri, are differences caused by growth that continued exceptionally late in summer, shoots 18 to 60 inches long. Normal, bearing peach trees that have a fair nitrogen supply each year are not usually caused by application of additional nitrogen to make such long, late shoot growth. The exceptionally late shoot growth made by peach trees in southern Missouri the first year after fertilization with nitrogen began, was due in part to the fact that they had been starved for nitrogen in preceding years and were not occupying all the soil available for them, and in part to lack of crop. In Berkeley, Elberta peach trees growing in sod with a nitrogen supply too low for more than an average of 3 to 5 inches of shoot growth do not drop their leaves appreciably earlier in autumn or blossom appreciably earlier in the following spring than trees growing in sod but given enough nitrogen to cause an average of 8 to 10 inches of shoot growth and a much greener and healthier appearance. Shoot growth, excepting a few suckers, was completed before midsummer on the low-nitrogen trees and only 2 to 3 weeks later on the rather high-nitrogen trees. Late-growing suckers from the large wood, of high-nitrogen or low-nitrogen trees, blossomed later, sometimes several weeks later, than these shoots 3 to 10 inches long, following the warmest winters.

Will Buds on Late-Growing Shoots Swell More Slowly than Buds on Weaker Shoots, During Warm Periods in Mid-Winter at Latitudes of About 37 to 40 Degrees?

At latitude 39° in Missouri, long shoots on peach trees caused by severe dormant pruning to grow much later than others, did not blossom later in the following spring; but some evidence suggested that during exceptionally warm periods in late December or January, buds on such late-growing trees did not swell as much as buds on weaker lightly-pruned trees. In winters having such late December or January warm periods, followed by killing temperatures, trees that, as a result of severe pruning (dehorning), continued growth late in summer, had more buds left alive than were left on unpruned trees with no late-growing shoots, though the reverse was true in winters when there had been no very warm period before the killing night. Experiments with twigs forced in a warm room suggested that buds from weak trees would start a little earlier than buds from trees that had made strong, late growth. However, it is hard to obtain convincing evidence by this method when the rest is nearly broken, because cutting the twig contributes toward further reduction of the rest influence.

Crane (3), referring to work by Howard (5), by Johnston (6), and by Knowlton and Dorsey (7), all working at latitude 39° or a little higher, suggested that because the rest is broken by January 1, it cannot after that inhibit swelling of buds. Of course the degree to which the rest is broken by January 1, is determined largely by the amount of chilling temperature to which buds have been exposed. If before January 1, there have been 2 or 3 months of temperature almost continuously below about 9 degrees C, probably the rest will be completely broken in all buds, but with less chilling weather it may not be broken until later, after very warm winters much later. Sometimes after the warmest winters in southern California, peach buds are still in the rest by May 1 or later. Further, when the bud will first grow, there may still be rest influence to prevent it from growing as fast as it otherwise would. In other words, during a warm period in January a bud on a weak twig and one on a strong twig might both be growing, but the one on the strong twig the more slowly.

Cutting twigs for forcing in a warm room, the method used by the workers cited, contributes toward breaking the rest, and so it does not follow that, because buds on such twigs taken in January will grow, the rest is completely broken. In the warmest parts of California the almond does not usually blossom until late in January, though the temperature is almost continuously favorable for growth, yet Hodgson (4) found that buds would grow on almond cuttings taken as early as November 20. The rest period of the almond is so slight that the cutting wound is enough to break it before there is any chilling weather.

Crane found that applying enough nitrogen to bearing peach trees to cause rather striking growth response did not delay the differentiation of flower parts in the bud. There is a slow development of the buds even when they are so profoundly in the rest that they cannot open; and so it is not certain that a degree of development in the unopen bud can be taken as indicating the ending of the rest.

Development of Peach Fruit Buds During, After, and Without a Chilling Period

It seemed advisable to grow trees in a continuously warm room so that the buds might be kept for a long time in the rest, to see what stages may be reached in development before the rest is broken. On September 9, 1932, two Lovell peach trees, with roots well established in garbage cans, had the leaves cut off, leaving stubs of petioles. One of these was placed in a greenhouse in which the temperature was not permitted to go below 15.6 degrees C and was usually much higher. The other was placed in a storage room at —1 to 0 degrees C, where growth was so slight that the petiole stubs were not abscissed for more than a month, though on the tree in the greenhouse they were abscissed within 5 days. A few buds (necessarily few because there were not many on the trees) were taken from each tree at convenient intervals and sectioned. In Fig. 1 are shown the stages of development in buds from each tree.

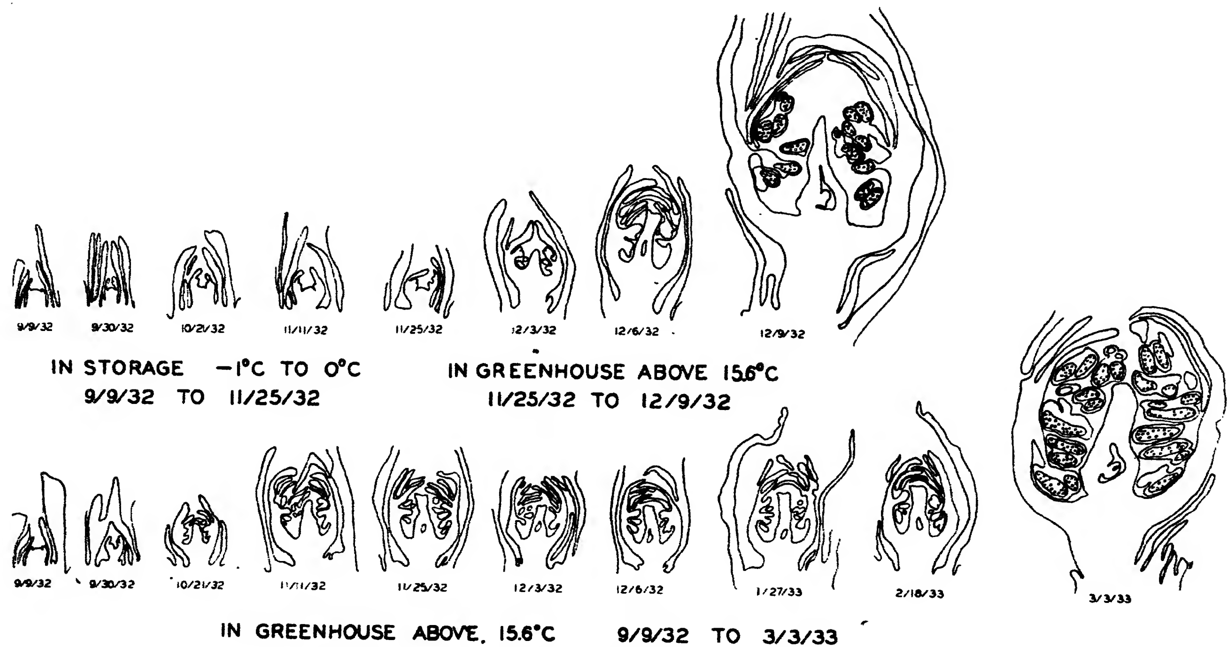

FIG. 1. Influence of the rest period on the development of fruit buds of the Lovell peach: Lower group, continuously warm, development slow, owing to the rest; upper group, held too cold for much development until November 25; with the rest broken there was as much development during 14 days in the warm greenhouse as buds represented by the lower group, continuously warm, made in 133 days.

On November 25 the tree in the storage plant was moved to the greenhouse, and placed beside the other. There had been very slight advancement in the buds of this tree from September 9 to November 25, but between November 25 and December 9 there was very rapid development: from only the slightest evidence of stamens to mature pollen. Nearly all the fruit buds on this tree had developed into fully open flowers by December 22. A few opened later into abnormal growths; a slight shoot with a few small leaves and a terminal flower.

By November 11, anthers in three of six buds from the tree continuously in the greenhouse had three to 5 sporogenous cells. They did not advance much beyond this until in February and the first mature pollen found was in a bud taken March 3. On this date other buds showed microspore mother cells at various stages of maturity. One flower was open on this tree on March 1, and several more on March 7. By May 3, 15 flowers had opened, but because the remaining buds seemed dormant the tree was put in the storage room at —1 to 0 degrees C and kept until June 23, when it was moved back to the greenhouse. By July 6, 1933, leaf buds formed in 1932 were swelling and most of the 1932 fruit buds were opening; by July 13, forty-nine fruit buds were nearly open; the remaining fruit buds were abscissed.

It is interesting to note that although flower bud development proceeded while the buds were in the rest, it proceeded slowly. On the tree that had been held in storage, there was as much development in the buds in 14 days (November 25 to December 9) as there was in 133 days (October 21 to March 3) in the earliest buds on the tree continuously in the greenhouse. In other words, there is development in the flower buds during the rest period, but that development is greatly inhibited by whatever it is that causes the rest period.

Summary

Buds on late-growing shoots are later in breaking the rest period, and may be later in blossoming in sections where there is less than about 3 months of chilling weather; mean temperature about 9 degrees C or lower.

However, even after winters so mild that the mean temperature for December, January, and February, is as high as 11.4 degrees C, growth prolonged no more than it can be on regularly-bearing peach trees by application of large amounts of nitrogen or by moderate pruning does not blossom later than weaker growth, if the weaker growth holds its leaves to a normal season of leaf fall.

Buds on twigs cut for forcing in winter will grow before the rest is broken enough to permit growth on uncut twigs.

Flower development proceeds in buds during the rest period when it is warm enough, but at a much slower rate than in buds exposed to growing temperatures after having been continuously at a temperature too low for growth until the rest was broken.

Stages of development to the microspore mother cell, and possibly

to mature pollen, may be reached while there is still rest influence enough left to prevent the bud from opening.

The facts set forth here seem to us to justify the opinion that, at any time after there has been chilling weather enough to break the rest in part, but before there has been enough to break it completely, buds on long, late-growing shoots will respond more slowly to warm periods, in development, in swelling, or in opening, than buds on shorter, early-maturing shoots.

Acknowledgment

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The Relationship Between Volume and the Dimensions of the Elberta Peach

By R. L. McMunn, *University of Illinois, Urbana, Ill.*

In many types of experiments with the peach it is desirable to follow the volume or weight increase of the fruit throughout the growing season. It is not always feasible to remove a part of the fruit to measure or weigh. A study was therefore undertaken to determine which measurement, *i.e.*, the diameter through the suture, the fruit length, the thickness or diameter perpendicular to the suture, or the average of the three, could be most accurately used as a growth index, when these dimensions were considered diameters of spheres, and volumes were calculated from these diameters. Obviously, since the peach is not spherical there is some error in using any one of these dimensions. Either one can be used, however, if the percentage of the error is known with some degree of accuracy. Since the peach fruit changes in shape as the season advances, studies on fruits in various stages of development should be made to determine the best diameter to use.

Studies with immature fruits:—Random samples of 100 peaches were picked from each of three plots, in the University orchard, Olney, Ill. The samples were collected from the vigorous 7-year-old trees on (1) May 18, 43 days after full bloom, when the stones were just outlined in the flesh, (2) on June 5, just after the June drop was over and the stones were hardening at the apex, and, (3) on June 15, when the stones were hard. Measurements to the nearest millimeter were made on each fruit, for each of the three dimensions outlined above, and the readings of each dimension or diameter were averaged. These averages were then considered as the diameter of a sphere in making the volume calculations for comparison. The average of the summation of the suture, length and thickness measurements was considered as the diameter of a sphere and from this value the average volume was calculated. For convenience, these calculated voulmes for each dimension will be referred to hereafter as the suture volume, the length volume, the thickness volume and the average volume. The volume of the fruit determined by the displacement method in a graduated cylinder will be referred to as the actual volume.

The data relative to immature fruit are presented in Table I, and show that in no case does the length volume or the thickness volume accurately represent the actual volume. The suture volume and the average volume, however, approach the actual volumes rather closely, and more closely as the fruit increases in size. On June 5 the greatest difference between the suture volume for any of the three lots was 7.4 per cent below the actual volume. By June 15, the greatest difference between the suture volume and actual volume had dropped to 4.1 per cent. The average volumes were somewhat closer to the actual volumes than were the suture volumes on May 18, but by

June 5 the differences between the average volumes and suture volumes were small.

The study indicates therefore, that of the three dimensions, the suture volume approximates the actual volume most closely, although not so close as the average of the three.

Studies with ripe fruit of unequal size:—The ripe peaches available were "tree-run" fruit from several thinning plots from the Olney orchard. In this series, three lots, of fifty fruits each, which varied greatly in size, were measured through the suture length and thickness, and volumes calculated from the average diameters, the same as with the immature fruit. These data are presented in Table II, and show that neither the length volume or thickness volume approach the actual volume as closely as does the suture volume or the average volume. The differences between the suture volume and actual volume were 6.9, 1.7 and 1.4 per cent respectively, while for the average volume there was a difference of 6.8, 2.5 and 6.3 per cent. From this it can be seen that in ripe fruit the suture volume is the most accurate of the different dimensions measured.

Studies with irregularly shaped fruit:—Since fruits which are "overgrown" in one dimension or the other are so often encountered in experimental work, one series was designed to determine the relative accuracy of the different calculated volumes as compared with the actual volume in such fruits. Forty fruits showing irregularities in growth were measured and the volume for the different dimensions calculated for each individual specimen. When these values were compared with the actual volume the same relation existed, *i.e.*, the suture volume was closer to the actual volume than were the others. As would be expected, some of the peaches had an actual volume greater than the suture volume, and with others the actual volume was less. The forty fruits averaged 88.7 cc in actual volume, while the calculated suture volume gave 82.7 cc or a difference of only 6.8 per cent. From this study it is apparent that if many irregularly shaped fruits are included in a sample, the extremes encountered compensate one another. It appears unnecessary to eliminate irregularly shaped fruit if the sample contains as many as 20 or more fruits.

Studies of fruits with the same suture diameter:—In this part of the study, all the fruit in a 12-bushel tree-run lot (more than 3000 fruits) was measured through the suture to the nearest millimeter and placed in classes varying by 1 millimeter. The length and the thickness of each fruit in each class was measured and averages were secured of each diameter. Also, averages were made of suture, length, and thickness diameters. The volume was calculated from each of the four averages and the actual volumes of the fruit of each size class were secured by the displacement method.

The curves in Fig. 1 are based upon the volumes calculated from the different dimensions and upon the actual volume of each size class. Neither the length of volume or thickness volume approach the actual volume as closely as does the suture volume or the average volume. The suture volume is even closer to the actual volume than

TABLE I—SHOWING THE ACTUAL AND CALCULATED VOLUMES OF ELBERTA PEACHES DURING THE GROWING PERIOD

Date measured	Average diameter (mm)				Actual Volume	Calculated Volumes (cc)			
	Suture	Length	Thickness	Average		Suture Volume	Length Volume	Thickness Volume	Average Volume
					Plot 1				
5/18....	19.19	26.33	15.38	20.30	4.25	3.69	9.54	1.90	4.38
6/8.....	37.89	44.62	30.96	37.82	26.50	28.46	46.51	15.53	28.32
6/15....	37.72*	44.54*	31.32	37.86	28.60	28.10	46.26	16.08	28.41
					Plot 2				
5/18....	17.56	24.88	14.10	18.85	3.45	2.83	8.06	1.46	3.50
6/8.....	36.39	43.36	29.35	36.33	23.80	25.25	42.80	13.03	25.08
6/15....	37.04	44.40	29.72	37.05	26.00	26.52	44.60	13.57	26.56
					Plot 3				
5/18....	18.32	25.38	14.08	19.26	3.80	3.21	8.58	1.46	3.74
6/8.....	37.53	44.66	30.04	37.41	26.40	27.65	46.64	14.13	27.39
6/15....	36.80*	45.84	30.84	37.83	27.20	26.09	50.30	15.29	28.28

*These slight reductions in size might have been eliminated with a larger number of measurements, or if the same fruits could have been used for the measurements at each date.

TABLE II—A COMPARISON OF THE ACTUAL AND CALCULATED VOLUMES OF MATURE FRUIT

Range (mm)			Average Diameter (mm)				Actual Volume (cc)	Calculated Volumes (cc)			
Suture	Length	Thickness	Suture	Length	Thickness	Average		Suture	Length	Thickness	Average
52–63	55–67	47–61	57.78	61.36	54.58	57.91	108.00	100.48	120.37	85.13	101.10
47–56	50–61	42–51	51.80	55.42	46.06	51.09	71.50	72.77	89.12	51.20	69.78
42–65	46–67	38–62	55.44	58.22	50.10	54.58	90.50	89.22	103.33	65.84	85.13

the average volume in all of the classes. In 30 of the 33 classes, there is less than 5 per cent difference between the suture volume and the actual volume. Undoubtedly the curves would have been more regular, especially in the larger classes, if more fruit had been included. The data show, however, that over a considerable range in fruit sizes the suture volume closely approximates the actual volume.

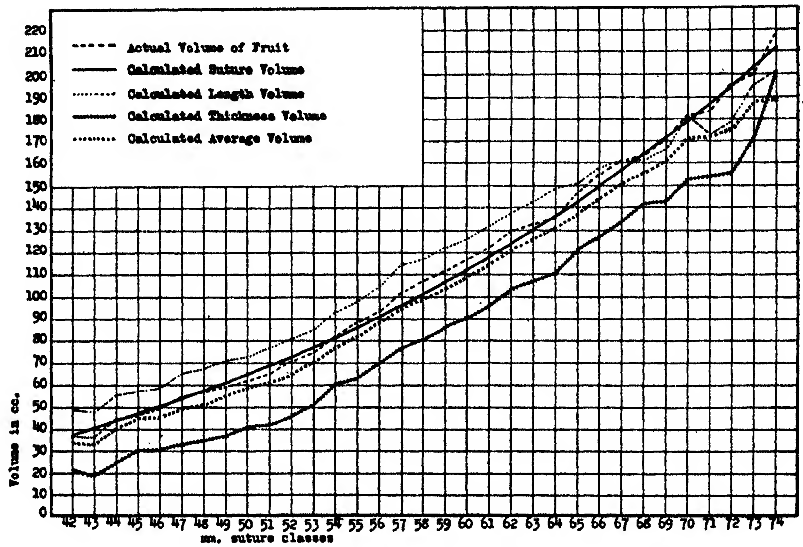

FIG. 1. Showing the actual volümes and calculated suture, length, thickness, and average volumes for ripe Elberta fruits of different suture diameters.

Although volumes were not calculated from circumference measurements, as used by some investigators, it is apparent that such calculations would introduce a greater error than would volumes calculated from the suture diameter or from the average of the suture, length and thickness diameters. This would be brought about, because thickness would be considered in making circumference measurements and volumes calculated from the thickness diameter always fall considerably below the actual volume. In Fig. 1 a curve plotted for a volume calculated from a circumference measurement would fall between the thickness volume and suture volume. It would appear that a circumference volume would change in relation to the suture and thickness volumes as the season advances. Early in the season a circumference volume would probably approach the suture volume, while after the final swell it would approach the thickness volume.

From this study it is apparent that volumes calculated from the suture diameter can be used as a reliable index of the increase in volume for this variety from the June drop to harvest. When the

stones are just outlined in the flesh the calculated suture volumes fall below the actual volume about 15 per cent. Such being the case, suture volumes calculated at this period can be corrected by multiplying by the factor 1.15. It is felt that with Elberta calculating the volume from the suture diameter can be used to advantage in those experiments where a knowledge of the volume increase of the fruit throughout the season is desired and samples cannot be removed from the tree for weighing or volumes determined by displacement.

Fruit-Seed Dimensions in Elberta

By M. J. Dorsey and R. L. McMunn, *University of Illinois, Urbana, Ill.*

IN the fourth report of the Illinois peach thinning investigations, it was shown that the larger peaches had the larger seeds. The data presented (1) was based on fruit separated in grading the crop from the thinning plots into size classes differing by ¼-inch. On this account, it seemed advisable this year to test this same point in a random sample separated into more closely integrated classes. Accordingly, in the studies this season, a random selection of approximately 3000 peaches was set aside from the thinning plots for this detailed study.

In getting the data each fruit was first measured through the suture diameter and thrown into classes differing by 1 mm. The other dimensions of each peach—the length and thickness—were then determined for the classes thus established. The fruit in each class was then weighed and the average weight of fruit determined by dividing the total weight by the number. The seeds were then extracted and the surface allowed to dry before they were weighed and measured. By taking the data in closely related classes in a large population, any changes in the relative dimensions of the fruit or the seed in fruit of different sizes, can be brought out.

Table I shows that even with a population approximating 3000 individuals, the extremes are represented by relatively small numbers. However, the data are presented as summarized because of the time and expense involved in working with so many individuals and also with the thought that other experimenters may wish to compare the dimensions of fruit grown in Illinois with that of fruits grown in other sections where the conditions may be quite different.

The points of interest in the data presented in Table I can be briefly stated. (a) The findings of last year, that the larger peaches tend to have larger seeds, are shown to hold true in a random selection thrown into classes separated by smaller intervals. In last year's report, it was mentioned that the range in the length of the stone might be less in classes separated more closely than ¼-inch intervals. In the summary of this year's measurements presented in Table I, the 59-mm class might be taken as representing approximately the mid point of the 2¼-to-2½-inch class of the data presented last year in Table III. In comparing the range in these two classes, it will be noted that last year the stones were from 3.7 to 4.6 cm long and that this year stones from the fruit of the 59-mm class varied from 3.6 to 4.3 cm in length. In the 60-mm class this year the range was from 3.5 to 4.7 cm, and in the 61-mm class, it was from 3.5 to 4.7 cm. From this it will be seen that last year's data fall in line with those obtained this year in showing that even in fruit of a given suture diameter the stone dimensions may vary considerably. (b) Within the range of the classes represented in the population

TABLE I—FRUIT SEED DIMENSIONS IN ELBERTA. THE DATA ARE ARRANGED IN THE TABLE ACCORDING TO THE SUTURE DIAMETER OF THE FRUIT

Average Fruit Dimension (mm)					Average Seed Dimension (mm)				
Number Fruits Measured	Suture Diameter	Length	Thickness	Average Weight of Fruit (gms)	Number Seeds Measured	Length	Suture Diameter	Thickness	Average Weight of Seed (gms)
11	42	44.5	34.7	39.1	11	35.4	24.4	16.0	5.4
5	43	45.2	33.7	39.8	4	36.0	25.0	15.5	6.3
23	44	47.2	36.3	44.1	23	35.9	24.9	15.9	5.2
38	45	47.9	38.5	47.2	38	35.6	24.8	15.4	5.8
58	46	48.2	38.8	50.7	57	34.9	24.4	15.8	5.6
103	47	50.1	40.1	54.6	103	35.6	24.6	15.8	5.9
132	48	50.3	40.6	55.7	132	35.9	25.1	16.1	6.2
158	49	51.4	41.6	59.2	158	35.8	25.2	15.9	6.3
152	50	52.2	43.0	62.9	150	36.6	25.4	16.3	6.4
156	51	52.9	43.5	66.1	154	36.6	25.7	16.4	6.6
143	52	53.5	45.5	70.0	142	36.9	25.9	16.5	6.7
121	53	54.6	46.1	73.5	120	36.8	26.1	16.6	6.5
126	54	56.3	48.6	81.8	125	37.4	25.8	16.7	6.7
126	55	57.3	49.7	87.2	126	37.7	26.1	16.7	6.6
125	56	58.4	51.1	94.2	36	37.9	26.6	16.9	6.5
117	57	60.3	51.3	101.9	23	37.9	26.6	16.7	6.6
157	58	60.7	53.8	105.9	150	38.4	26.6	17.0	6.9
144	59	61.2	54.9	111.5	134	39.1	27.0	17.4	7.5
145	60	62.1	56.3	116.8	134	39.2	27.2	17.2	7.4
148	61	63.2	56.9	121.7	138	39.2	27.4	17.4	7.4
131	62	63.3	58.8	127.5	123	40.1	27.1	17.9	7.9
120	63	64.9	58.9	133.7	106	40.3	28.1	17.8	8.1
128	64	65.7	58.4	139.0	108	40.6	28.3	17.8	7.9
117	65	65.2	61.5	146.2	96	40.5	28.7	18.1	8.3
104	66	67.2	62.4	153.6	92	40.5	28.7	18.2	9.1
81	67	67.4	63.5	159.4	69	41.4	29.4	18.8	9.1
56	68	67.8	64.8	161.1	48	41.9	29.8	19.5	8.6
44	69	68.2	64.9	171.5	40	41.6	30.3	19.4	9.1
30	70	70.3	66.4	179.7	28	42.7	30.0	20.1	9.6
11	71	69.2	66.2	182.7	11	42.3	30.0	19.9	10.4
6	72	70.0	66.8	190.0	6	42.7	30.0	20.1	9.8
2	73	72.0	69.0	205.0	2	46.0	32.0	20.0	12.5
4	74	72.7	71.2	213.7	4	44.0	32.5	21.5	11.3
3022					2694				

selected for this study, the largest seeds are more than double the weight of those in the smallest class. On the other hand, within this same class range the weight of the fruit increases over six times. The relative rate of increase in the seed as compared with the flesh is readily seen by plotting curves for the fruit-seed weight as given in Table I. (c) As compared with the suture diameter the thickness of the fruit of Elberta tends to increase in the larger sizes; that is, in the final swell, the fruit grows more, relatively, in thickness than in length or through the suture diameter. (d) In contrast to the relative dimensions of the fruit, the seed seems to increase proportionately in all dimensions, except in the largest fruits, where it tends to grow somewhat faster relatively through the flat diameter, *i. e.*, in thickness. In this population, however, there were not many of the larger fruits, so this tendency could not be measured accurately.

The seed-fruit proportions found in Elberta would be expected to vary in minor details in other varieties. The tendency, however, for the larger peaches to have the larger seeds is probably general in the species. From the standpoint of thinning or increasing the size of the fruit by any of the other cultural variables, it would seem that seed size must also be increased. With one of the outside dimensions of the fruit known, the expectation as to seed or stone size can be fairly accurately foretold from the data presented.

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Size and Growth Relations of Fruit in Splitting of Peach Pits

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THE occurrence of split-pit in peaches has been mentioned from time to time. Aubin (1) records the occurrence of 15 per cent split-pits among the ripe fruits of Hale's Early on branches that had been ringed, but not on similarly treated branches of the variety Amsden. He ascribes the cause to excess of elaborated sap. The fruit of the Hale's Early from the ringed branches ripened 22 days earlier and averaged 36 grams heavier than the fruit from the unringed branches. Blake (2) reported that in New Jersey split-pits commonly occur on vigorous trees that have been partly girdled, as by winter injury or some other factor which prevents the downward movement of elaborated food. He believes that nutritional conditions in the tree are such that the forcing effect of the large food supply is made available to the fruit early in the season before the pits have hardened. The largest fruits were the ones most commonly affected. Miki (3) reported that the percentage of split-pit is higher in the earlier ripening fruits within the same variety. Early ripening of these fruits is not caused by the split-pit condition, but rather by the factors associated with split-pit, conditions which are associated with well-developed and rapidly growing fruits.

An investigation dealing with the occurrence of split-pit in peaches was begun in 1929. The data reported in this paper deal only with one phase of the investigation, that concerning the size and growth relations of split and unsplit fruits. Most of the work has been done with clingstone varieties which are used for canning. One of these, the Tuscan, frequently has an especially high proportion of split-pits. Much of the data herein reported deals with this variety.

The data were obtained by tagging individual fruits early in the season and measuring these same fruits at about weekly intervals throughout the season. At harvest the fruits were picked and their condition with respect to split-pit determined. The number of fruits in each group varied from 50 to 100 in each year, except 1933. In this year some groups contained 300 fruits for the purpose of permitting the making of distribution curves. No tags were added during the season and only the measurements of those fruits which were examined at harvest time were used. The data are for fruit diameters, measured with calipers graduated to 1/10 millimeter. In most cases the cross diameter, rather than the longitudinal or suture, has been measured.

There seems to be general agreement in the literature that the split-pit condition is associated with conditions which are favorable to the production of large fruit and early maturity, although these factors have not been suggested as causing this condition. Our observations show that there may be a large variation in the amount of split-pit produced in different years, among individual trees in the

same year, and even among different locations on the same tree. In the following tables the data have been so grouped as to show the size relations between split and unsplit fruit, between average size of fruit in different years, and between average sizes of fruit on individual trees which differ widely in percentages of split-pits. The volumes of the fruit have been calculated in cubic centimeters from the cross diameter, assuming that the fruit is a sphere.

The use of the cross diameter as a means of comparing the size of split and unsplit fruit is accompanied by some danger inasmuch as the result of the splitting, rather than an associated condition, may be measured. It is well known that split-pit fruit is much larger in the cross diameter than unsplit fruit, as maturity approaches. It is difficult to know just when the separation of the halves of the pit is reflected in the increased size of the cross diameter. Our observations indicate that macroscopic evidence of the splitting can be found about the beginning of the third growth phase. The data in the following tables have, therefore, been confined to the date of the first measurement, the approximate date of entrance into the second phase and the date which approximates the end of the second phase. It is believed that the data for the first and second measurements are not influenced by the actual split-pit condition, and in all probability the third measurement does not reflect this condition, as it represents a date which definitely precedes the beginning of the final swell.

The year 1929 produced the largest number of split-pit fruits, and 1930 the smallest of the years covered by the investigation. In 1929 there was a very light crop because of a general spring frost and in 1930 perhaps the largest crop per tree of any year during the last five. In Table I are presented data showing the size of fruit at the

TABLE I—Comparison of Average Size of Tuscan Peaches at Beginning of Second Growth Phase, in Relation to Percentage of Split-pit

Orchard	Per cent Split-pit in Orchard		Average Volume per Fruit (cc)	
	1929	1930	1929	1930
Andross	40	4	19.2	11.6
Galbraith	50	7	20.8	12.9

beginning of the second growth phase in 1929 and 1930 and the percentage of split-pits in each of the two years. The data indicate that there is considerable difference between the size of the fruit in the 2 years. The first growth phase covered approximately the same length of time in both years. Confirming evidence of the accelerated rate of growth is offered in the average daily growth increment just preceding the beginning of the second phase in the 2 years. In 1929 the fruit on the Galbraith ranch made an average growth increment of .672 cc per day for the 13 days preceding the inception of the second phase; in 1930 the fruit on the same ranch made an average increment of .358 cc per day for the 14 days prior to the beginning of the second period.

The data in Table II present comparisons between the size of the tagged fruit and the percentage of split-pits on individual trees. The data in this table are for unsplit fruit only.

TABLE II—COMPARISON OF AVERAGE SIZE OF TUSCAN PEACHES AT BEGINNING OF SECOND GROWTH PHASE, ON INDIVIDUAL TREES AND THE PERCENTAGE OF SPLIT-PIT PRODUCED BY THESE TREES

Location and Tree	Date	Per cent Split-pit	Vol. (cc)	Location and Tree	Date	Per cent Split-pit	Vol. (cc)
Andross				Bandy			
L-4.....	5/21/29	42.0	18.8	E-3...	5/17/30	34.0	16.1
L-7.....	———	21.0	15.1	E-5...	———	26.0	17.6
Galbraith..				E-7...	———	0.7	12.0
L-3.....	5/12/30	7.4	16.8	Bandy			
L-4.....	———	10.2	15.9	E-2...	5/8/31	3.7	15.1
L-5.....	———	3.6	13.4	E-3...	———	12.7	17.3
				E-4...	———	4.9	16.5
Sullivan				Creelman			
E-1.....	5/12/30	8.7	13.9	E-1...	5/6/31	2.2	18.8
E-2.....	———	1.3	14.3	E-2...	———	16.2	21.7
E-3.....	———	23.1	18.8	E-3...	———	14.3	22.8

The accuracy with which the data picture the actual size conditions on any tree depends upon how representative the selection has been. There does, however, seem to be a pronounced tendency toward larger fruit on the trees with the greater percentages of split-pits.

Tables III and IV present data in which the sizes of split and unsplit fruits are compared on different dates. The figures in Tables III and IV are for volumes calculated from the average cross diameter. The data for the unsplit fruits are for all the tagged fruits in the group that were not split. The total number of fruits in any one group varies from 50 to 300. The number of split-pit fruit varies from 2 to 96, and represents a wide range of proportions of the total fruit.

Data obtained for the suture diameter in 1929 and 1930 show the same relative size relationships for split and unsplit fruit as do those for the cross diameter.

There are 20 groups in which comparisons are made in Table III. These comparisons extend over 4 years, are for a number of different orchards, or for different blocks in the same orchard. They offer a wide range of conditions under which the fruit was grown, and also a wide range of selection of fruit. If each date is considered as a unit, there are 54 comparisons for size of which there are but four cases where the split-pit fruit is not larger than the unsplit. In some cases the difference is quite small, but the consistent trend of the data would seem to indicate its significance. If the volume increase is considered, there are 34 possible comparisons. Of these, there are three cases where the split-pit fruits made a smaller increase than the unsplit. There are five additional cases where the increase in volume of the split-pit fruit has been greater than the

TABLE III—Comparison of Average Size of Tuscan Peaches with and without Split-Pit, at Time of First Measurement, End of First Growth Phase, and at End of Second Growth Phase. 1929–1932

Orchard	Date	Volume (cc)		Volume Increase (cc)	
		Split	Not Split	Split	Not Split
Galbraith.......E*	5/10/1929	11.6	10.1	—	—
Galbraith.........	5/29	21.7	20.6	10.1	10.5
Andross.........E	5/21	16.8	16.1	—	—
Andross.........L	5/21	19.7	16.2	—	—
Andross.........E	4/30/1930	8.4	8.3	—	—
Andross..........	5/12	13.6	11.5	5.2	3.2
Andross..........	6/2	19.5	16.1	5.9	4.6
Sullivan........E	4/28	9.0	8.6	—	—
Sullivan..........	5/12	16.8	15.4	7.8	6.8
Sullivan..........	6/2	22.5	20.6	5.7	5.2
Galbraith.......E	4/28	8.8	7.3	—	—
Galbraith.........	5/12	15.2	12.2	6.4	4.9
Galbraith.........	6/2	21.5	16.4	6.3	4.2
Galbraith.......L	4/28	9.1	9.4	—	—
Galbraith.........	5/12	15.9	16.1	6.8	6.7
Galbraith.........	6/2	19.5	19.9	3.6	3.8
Bandy..........E	4/26	5.4	4.7	—	—
Bandy...........	5/17	18.3	14.6	12.9	9.9
Bandy...........	6/9	23.0	18.5	4.7	3.9
Bandy..........M	4/26	5.4	5.1	—	—
Bandy...........	5/17	17.3	14.1	11.9	9.0
Bandy...........	6/9	22.8	18.5	5.5	4.4
Bandy..........L	4/26	5.5	5.1	—	—
Bandy...........	5/17	16.2	14.6	10.7	9.5
Bandy...........	6/9	19.7	18.0	3.5	3.4
Creelman.........	4/21/1931	7.9	7.4	—	—
Creelman.........	5/6	22.8	20.8	14.9	13.4
Creelman.........	6/1	32.0	28.3	9.2	7.5
Sullivan..........	4/20	7.9	5.4	—	—
Sullivan..........	5/6	19.5	15.6	11.6	10.2
Sullivan..........	6/1	26.1	20.8	6.6	5.2
Tharpe...........	4/22	10.4	9.2	—	—
Tharpe...........	5/6	22.5	20.4	12.1	11.2
Tharpe...........	6/1	34.5	31.1	12.0	10.7
Bandy..........E	4/24	9.2	8.7	—	—
Bandy...........	5/8	16.4	15.5	7.2	6.8
Bandy...........	5/29	21.9	20.9	5.5	5.4
Galbraith.........	4/22	9.5	8.0	—	—
Galbraith.........	5/6	18.8	16.2	9.3	8.2
Galbraith.........	6/1	24.4	21.1	5.6	4.9
Woodbridge.......	4/29	10.8	9.5	—	—
Woodbridge.......	5/22	24.8	23.4	14.0	13.9
Galbraith.........	4/28/1932	8.0	8.7	—	—
Galbraith.........	5/17	21.5	19.7	13.5	11.0
Galbraith.........	6/6	27.4	24.6	5.9	4.9
Tharpe..........E	4/28	8.2	7.1	—	—
Tharpe...........	5/17	18.8	18.0	10.6	10.9
Tharpe...........	6/6	22.8	21.9	4.0	3.9
Tharpe..........L	4/28	9.0	7.4	—	—
Tharpe...........	5/17	18.1	15.4	9.1	8.0
Tharpe...........	6/6	23.2	18.8	5.1	3.4
Sullivan..........	4/27	5.1	4.3	—	—
Sullivan..........	5/17	22.5	20.6	17.4	16.3
Sullivan..........	6/6	31.1	27.8	8.6	7.2

*E, M, L, refer to locations.

unsplit oy but 0.1 cc. In all other cases the differences are rather large. The data for the increase in volume are for periods covering the latter part of the first growth phase and for the entire second growth phase.

In Table IV data are presented for varieties other than Tuscan. In this table measurements for only two dates, both very early in the growth of the fruit, are given. Data for later measurements agree with those in Table III with respect to the increasing difference in the size of the split and unsplit fruit.

TABLE IV—COMPARISON OF SIZES OF SPLIT AND UNSPLIT PEACHES. DATES ARE FOR FIRST MEASUREMENT AND BEGINNING OF SECOND GROWTH PHASE

Location	Variety	Date	Volume (cc)		Volume Increase (cc)	
			Split	Not Split	Split	Not Split
			1930			
Andross........	Phillips	4/30	7.6	6.0	—	—
Andross........	Phillips	5/20	16.2	12.5	8.6	6.5
Galbraith......	Phillips	4/28	8.7	6.8	—	—
		5/20	22.6	16.5	13.9	9.7
			1931			
Bandy.........	Phillips	4/17	2.7	2.5	—	—
		5/15	19.2	17.8	16.5	15.3
University Farm	Phillips	4/24	3.3	3.4	—	—
		5/15	15.4	14.4	12.1	11.0
			1932			
Sullivan........	Phillips	4/27	4.9	4.7	—	—
		5/17	16.8	15.1	11.9	10.4
	Gaume	4/27	7.1	6.3	—	—
		5/11	21.1	19.0	14.0	12.7
University Farm	Lovell*	4/29	7.2	7.0	—	—
		5/18	25.2	23.8	18.0	16.8
			1933			
University Farm	Lovell*	5/29	7.0	6.6	—	—
		6/26	23.4	21.9	16.4	15.3
University Farm	Phillips	5/11	5.6	5.5	—	—
		6/17	29.0	27.4	23.4	21.9
University Farm	Muir	5/11	5.5	4.9	—	—
		6/17	36.6	33.5	31.1	29.6
University Farm	Elberta	5/15	10.0	10.5	—	—
		6/17	34.0	32.3	24.0	21.8
University Farm	Palora	5/8	5.3	5.1	—	—
		6/10	30.0	28.7	24.7	23.6
Sullivan........	Phillips	5/9	7.0	6.3	—	—
		6/8	21.3	19.7	14.3	13.4

*Data for Lovell peaches were furnished by Mr. Omund Lilleland of the Division of Pomolgy.

The data in this paper show that there is a close relationship between the size or growth rate of fruits and the occurrence of split-pits. This relationship holds in all cases where comparison is pos-

sible, between different years when the difference in split-pit was large, between individual trees that have different amounts of split-pit, or between fruits that are and those that are not split when they are borne on the same trees and previous to the time when there was any macroscopic evidence of splitting. This is in agreement with the observations of our growers, that years of very large sizes are also years of high percentages of split-pits.

The data do not indicate, however, that only large fruits have split-pits. No reasons can be assigned from these figures as to the actual conditions which produce split-pit peaches. Enough fruits have been measured to give a normal distribution of sizes, and in this distribution the tendency is for the split-pit fruits to occur among the larger sizes. Tables III and IV represent measurements on approximately 3000 fruits. The occurrence of size differences so early in the season suggests that the causes for the different growth rates are probably effective throughout the season. The data cover a period of 5 years and a number of widely separated orchards. The circumstances under which these fruits developed, in all probability, cover a wide range of conditions which are supposed to affect the growth rate of fruits, such as leaf area per fruit, total crop on the tree, a particularly favorable location on the tree and soil and climatic conditions. These facts would seem to offer additional weight to the suggestion that the occurrence of split-pit is very closely associated with those conditions which cause an increased rate of growth of the fruit.

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Further Studies of Peach Fruit Growth

By RICHARD V. LOTT, *Mississippi State College, State College, Miss.*

A STUDY was made of the growth and chemical composition of Hiley and Elberta peaches from the time when the stone was first hard enough to separate from the flesh until the flesh was soft ripe. The trend of all growth measurements and all chemical analyses was very similar for the two varieties.

When growth was measured by increase in average diameter, by volume increase, or by green weight increase, a period of slow growth, similar to that mentioned by previous investigators, existed until the final swell, or final period of rapid growth began, 4 weeks before harvest. When growth was measured by dry weight increase, no period of slow growth was evident. This is the only one of the mehods used for measuring growth which takes into account the increasing dry weight percentage of the stone and kernel, and is, therefore, the only physiologically correct one.

The stone increased rapidly in dry weight until 4 weeks before harvest and then decreased until harvest. The final swell of the flesh began immediately after the stone reached its maximum dry weight. The dry weight of the stone exceeded that of the flesh for approximately 2 weeks before the stone reached its maximum dry weight.

The kernel reached its greatest dry weight increase 4 weeks before harvest and its greatest percentage of the fruit 3 weeks before harvest.

In Hiley, 59 per cent, and in Elberta, 68 per cent of the total dry weight of the flesh accrued during the last 4 weeks before harvest. This shows the great metabolic activity of the flesh during the final swell. It is, perhaps, significant that this period of greatest metabolic activity of the flesh did not begin until the stone had reached its maximum dry weight and maximum percentage of the fruit and the kernel had reached its maximum dry weight increase and was near its maximum percentage of the fruit. This indicates that the stone and kernel are the dominant parts of the fruit until their period of greatest metabolic activity is past.

All chemical determinations were calculated on the basis of grams per 100 fruits. In the stone, nitrogen increased for 3 weeks then decreased, with a marked decrease after it had reached its maximum dry weight; sugar decreased throughout the period; starch and hemicellulose increased until the stone was near its maximum dry weight, then decreased; and ash increased for 2 weeks, then decreased, with a marked decrease during the last 4 weeks.

Nitrogen, sugar, hemicellulose, ash, and ether extract increased in the kernel throughout the investigation, while starch increased until the kernel reached its maximum dry weight increase and then decreased.

All constituents of the flesh except hemicellulose increased throughout. Hemicellulose increased until the final swell, then de-

creased. In Hiley, 70 per cent, and in Elberta, 81 per cent of the total amount of sugar in the flesh at harvest accrued during the final swell.

The above data show that the period of slow growth of the fruit mentioned by several investigators is really one of slow growth in the flesh only, both the stone and the kernel making their most rapid dry weight increase during this period. Furthermore, the stone apparently reaches physiological maturity during this period since it reached its maximum concentration of all materials except sugar, which constantly decreased.

The final swell of the fruit was characterized by a marked increase in size, dry weight, and sugar content of the flesh; by a decrease in dry weight in the stone, accompanied by a decrease of nitrogen, carbohydrates, and ash; and by a decreased rate of dry weight increase of the kernel, but increasing amounts of nitrogen, sugar, hemicellulose, ash, and ether extract, indicating that the kernel had not reached physiological maturity at harvest. It also seems probable that materials were being translocated from the stone to the kernel during this period since all constituents of the stone were decreasing while those of the kernel, except starch, were increasing. There may have been some translocation from the stone to the flesh also, since all constituents of the flesh except hemicellulose were increasing.

Growth Study of the Plum Fruit—I
The Growth and Changes in Chemical Composition of the Climax Plum

By O. LILLELAND, *University of California, Davis, Calif.*

A STUDY of the growth of deciduous fruits is being made at Davis in conjunction with field studies in fruit thinning. An understanding of the growth of the various components of the fruit and a detailed knowledge of the increase in size of the fruit as a whole have been helpful in formulating and interpreting the field experiments. Data on the Elberta peach and Royal apricot have been published (1, 2), and indicate that these two fruits exhibit distinct cyclic growth. In general, with these fruits, there appears to be three definite growth periods. The first is one of rapid growth followed by a period of depressed growth, which, in turn, breaks into a period of accelerated growth. This last period, in which the fruit makes its greatest increase in size, is often termed the period of "final swell," and field experiments seem to indicate that thinning can be delayed until the inception of this period without appreciable reduction in the size of the fruit. It is possible, by weekly measurement of the cross diameters of the Royal apricot and Elberta peach, to establish the duration of these periods rather accurately and to use these data as a guide in the thinning schedule.

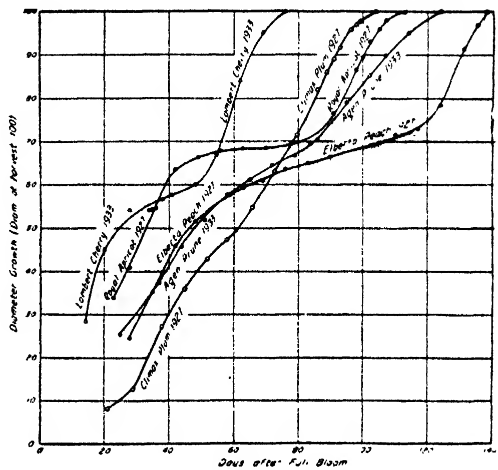

FIG. 1. Growth of deciduous fruits from cross-diameter measurements. Only a slight indication of cyclic growth is evident in the Climax plum.

GROWTH OF PLUMS IN GENERAL

The data in Fig. 1 indicate that the Climax plum shows only slight periodicity (erroneously interpreted and reported by me in an earlier publication (2) as showing no periodicity) in comparison to the Royal apricot, Elberta peach, and the Lambert cherry. Some growth data of individual Climax fruits are presented in Fig. 2. Cyclic development is evident in all the fruits, though less marked in the 1927 season than in 1928. It is more difficult to discern in the

case of the Climax plum the abrupt change in the rate of growth that is characteristic of the apricot data and that so clearly defines the commencement of this third growth period. A better criterion for ascertaining the period of "final swell," and in establishing a thinning schedule for the Climax variety, is the increase in weight (or volume) of the fruit. Pronounced cyclic diameter growth is, however, characteristic of other plum varieties, *viz.*—the Agen, (Fig. 1), Robe de Sargeant, and Tragedy plums.

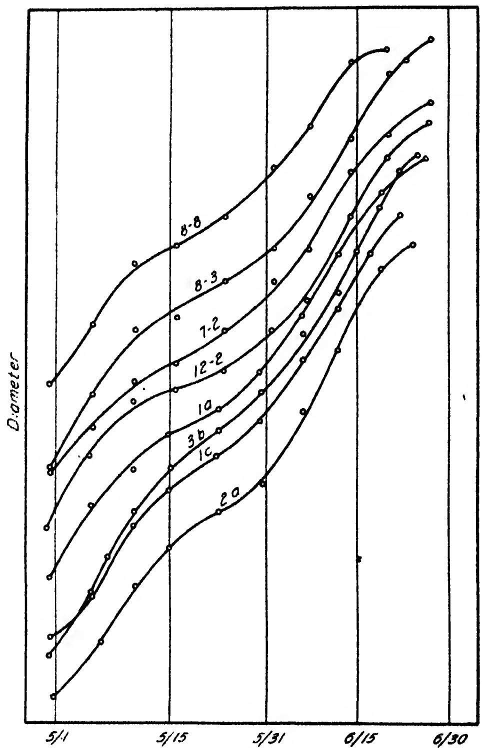

Fig. 2. Growth curves of individual Climax plums. Fruits 1a, 1c, 2a, 3b, are from 1927 data; 7–2, 8–3, 8–8, 12–2 from 1928 data.

Tukey (3) has recently reported that early maturing varieties of cherries have less of a retarded growth period and a higher percentage of aborted kernels than do the later ripening kinds. The Climax fruits which were measured in 1927 were harvested, the kernels examined, and the data regrouped on the basis of kernel abortion. The growth curve of the fruits having aborted kernels is practically identical with that of the fruits having well-filled kernels. No information was obtained regarding the size of the embryo when abortion occurred. Kernel abortion in the individual fruit does not seem to affect the amount of retardation of growth exhibited by this same fruit, since fruits with fully-developed kernels seem to show identical diameter growth behavior with those having aborted kernels. It is also doubtful that the high percentage (50 per cent) of aborted kernels found in the Climax plum can be an influence in the growth of all the fruits on the tree. This statement is substantiated by some data on Elberta peaches. In 1929, when frost reduced the crop on a 10-year-old Elberta peach tree to only 14 fruits, these fruits still exhibited cyclic growth (1). There would be very little or no nutritional competition between kernel and flesh growth under the above conditions. There must have been more than ample

reserves in the tree to care for the needs of both kernel and flesh. Also, in the case of the Climax plum, competition from the kernel would come mainly during the third period. This component makes only a minor increase in total solids during the depressed period. These data then would seem to contradict any hypothesis that kernel development might produce a temporary nutritional depletion in the tree resulting in a period of retarded growth of the fruit. If a dominance of reproductive tissues does control the development of the flesh of the fruit (5), it is probably in the nature of a growth stimulant not easily subjected to experimentation.

Growth of the Climax Plum as Measured by Weight or Volume Increase

The marked growth periodicity determined from diameter measurements in the Royal apricot (2) and the Elberta peach (1) was as strikingly reflected in concurrent periodic increases in the weight and volume of the fruit. This is to be expected so long as there is no change in form or density of the fruit studied. The increase in green weight of the Climax plum fruit is shown in Fig. 3. There is no abrupt break to suggest the termination of the first period of growth, but there is a definite point of inflection about June 1 which marks the beginning of the rapid growth of the flesh (the period of final swell). Calculations indicate that the Climax plum is rapidly changing in form at this date and explain the discrepancy between the diameter and weight curves. As noted above, the abrupt change in rate of increase in weight of the Climax fruit is a more definite criterion to use in establishing the period of final swell than are the diameter data. The earlier interpretation of the slight change in diameter growth rate as marking the time of the rapid flesh development is confirmed.

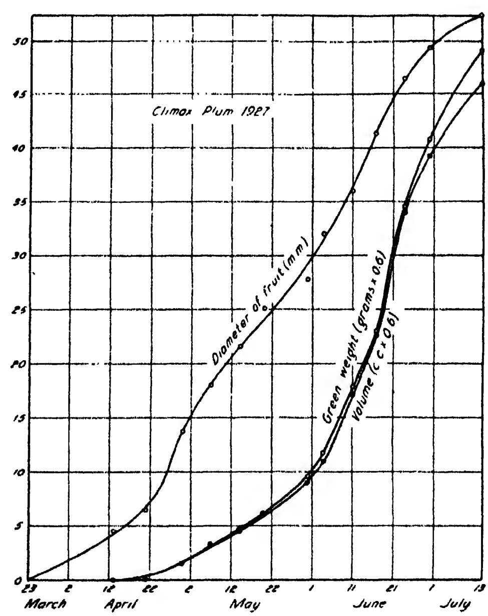

Fig. 3. Growth of the Climax plum in cross-diameter, green weight and volume.

The method used to calculate the change of form may be of interest. For objects having the same form, this relationship is true, $V \propto L^3$ (when V is the volume and L is any linear dimension). The density in the case of many deciduous fruits is fairly constant (Fig. 3) throughout their growth and closely approximates unity, so that this relationship is also true, $W \propto L^3$ (when W is the weight and L is any linear dimension).

The two relationships can be written $\frac{V}{L^3} = K$, $\frac{W}{L^3} = K^1$. When the form of the fruit remains the same K or K^1 will have the same value throughout the entire period of growth. Table I gives the values of K for the 1927 Climax plum data.

TABLE I—CHANGE IN FORM $\left[\frac{\text{Volume}}{\text{Radius}^3}\right]$ OF THE CLIMAX PLUM IN 1927

4/13	4/30	5/2	5/14	5/20	5/31	6/4	6/11	6/17	6/24	6/30	7/13
6.7	7.9	7.5	5.8	5.7	5.6	4.4	4.8	4.7	4.5	4.3	4.2

It is evident from these data that the Climax plum does not grow at equal rates in all directions. Similar calculations of the peach and apricot data do not show such marked changes in form and account for the closer agreement between cross diameter and weight or volume growth curves with these fruits. In the Climax plum there also appears to be a definite form associated with each growth period. During the first period the volume of the Climax plum is approximately 75 per cent greater than a true sphere of the same (cross) diameter. In the second period this figure drops sharply to about 37 per cent, and in the last period there is another abrupt change to an average of 7 per cent. Growth analyses, based on volumes calculated from diameter measurements of fruits which change their form, may obviously be grossly in error.

In 1927, the Climax plum matured approximately 16 weeks after full bloom. The period of final swell was limited to the last 6 weeks growth, during which time the fruit gained 80 per cent of its green weight at harvest. In 1925 the Climax plum gained 65 per cent of its green weight during the last 4 weeks of growth. The growth, as measured by increase in volume, is practically identical with the green weight data, suggesting that any changes in density of the fruit as it develops on the trees are of small magnitude.

Development of Flesh, Endocarp, and Kernel-Growth as Measured by Dry Matter Increases

The dry matter contents of the pericarp and kernel were determined during the early stages of growth and of the endocarp and flesh as soon as these could be separated from each other. These data are presented in Fig. 4. The development of these components is in agreement with those of the apricot and peach. The endocarp is formed first and its growth takes place mainly during the second

period. The accelerated growth of the flesh is practically confined to the third period, during which time the endocarp makes little or no growth. The kernel also exhibits accelerated increase in dry matter during the last stage of growth. The rate of accumulation of carbohydrates by the fruit in this period of final swell is of much greater magnitude than in the other two periods. This should be reflected in a marked withdrawal of carbohydrates from the storage tissue of the bearing tree.

A comparison of the rates and amounts of total solids withdrawn by the Climax fruit during the three periods is given in Table II. Davis (4) has shown that this enormous increase in the growth of the fruit at the period of final swell is reflected in a distinct concomitant depletion of starch in the wood and bark of the bearing trees.

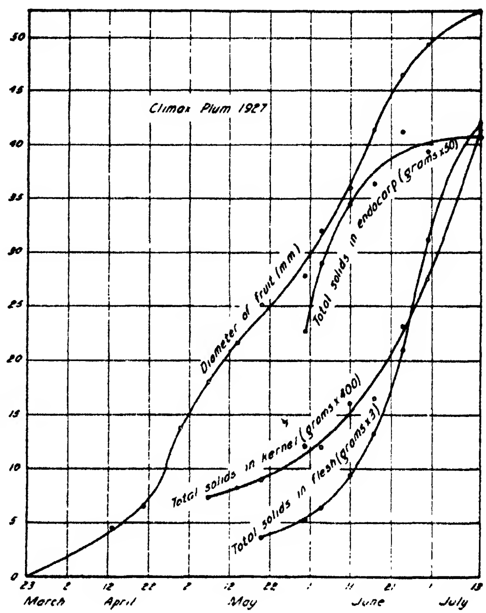

FIG. 4. Development of total solids in the flesh, endocarp and kernel in the Climax plum fruit.

While the changes at pit-hardening time (second growth period) are marked, when a study is made of the percentage composition of the endocarp, the actual increase in dry matter of the young fruit as a whole at this stage is not of great magnitude. It seems that the importance of thinning before the period of pit-hardening may have been exaggerated. In 1927, the Climax plum had accrued up to the inception of the third period of growth only 15 per cent of the total solids found in the fruit at harvest. Much of the fruit thinning in California is probably done after the development of the endocarp is well on its way and this fruit generally attains satisfactory size. The

TABLE II—INCREASE IN TOTAL SOLIDS—CLIMAX PLUM FRUIT

Period	Extent	Increase in Total Solids	Rate per Day	Ratio
I......	3/23 to 5/7	.667	.0121	1
II......	5/8 to 6/4	2.030	.0725	6
III......	6/5 to 7/13	12.200	.3128	26

hazards of spring frosts and the necessity of spring irrigation are some of the practical features that actuate the growers to delay thinning. These data show that the growth of the fruit does not accelerate rapidly until relatively late in the season and indicate why this practice of later thinning is satisfactory.

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A Comparative Study of the Developing and Aborting Fruits of Prunus Persica

By Thomas J. Harrold, *University of Georgia, Athens, Ga.*

Abstract

This paper will appear in full in the *Botanical Gazette.*

DEVELOPING and aborting fruits of the peach were examined microscopically and macroscopically. The development of the normal megagametophyte and fruit of the peach agrees with facts already established for other members of the genus *Pruns.*

The dropping of pistils occurs in three distinct waves during the first growth period, and each bears a constant relation to the developing pistils. The aborting fruits differ from developing fruits mainly in degree of development. The possibility is indicated that a disorder in the region of the chalaza may occur prior to cessation of development of gametophyte or embryo.

Growth of the Peach Embryo in Relation to Growth of Fruit and Season of Ripening

By H. B. Tukey, *Experiment Station, Geneva, New York*

GROWTH of the peach fruit occurs in three stages, as shown by Connors (6), namely: "1. Rapid devolpment of the fruit apparently due mainly to increase in the size of seed part. 2. Rest period during which the seed is formed and the stone becomes hard. 3. Period of rapid growth of flesh to maturity." Similar growth periods in terms of dry and fresh weight have been shown by Lilleland for the apricot (15) and for the peach (16). In seeking an explanation for the stage of retarded pericarp development he emphasized the abruptness of the changes from one stage to another, and considered the competition for food substances used in forming the stone to be the important factor. He found no relation between twig growth and delayed pericarp development, although Dorsey and McMunn (10) seemed to find a slight correlation.

Studies of growth of the peach have been extended by Lott (17) to include chemical composition. He noted a loss in ash, nitrogen, starch, sugar, and hemicellulose in the stony pericarp, and an increase in ash, nitrogen, sugar, starch, hemicellulose, and ether extract in the seed during the same period.

In studying embryo abortion in cherries, Tukey (20) found similar periods of pericarp development and showed the suppressed development of the embryo during the first stage of rapid growth of pericarp and nucellus and integuments, and the rapid growth of the embryo during the period of retarded development of the pericarp. He found the duration of retarded pericarp development to be shorter in early-ripening than in late-ripening varieties, and correlated these facts with embryo abortion in early-ripening varieies, suggesting a nutritional relation inasmuch as abortive embryos could be grown in artificial culture when removed at proper stages of development (21). The failure of early-ripening varieties of peach to develop viable seed has been noted by Connors (6), Chandler (5), and Sakaguchi (19). Development of the pericarp of the peach and the hardening of the stony pericarp with reference to thinning and other cultural practices have been considered by Farley (13), and by Dorsey and McMunn (9, 10, 11, 12). The relation of physical characteristics, chemical composition, and histological structure of the fruit flesh to development and ripening have been discussed by Blake, *et al.* (1, 4, 18).

The problem presented by these considerations is the interrelation of developing parts of varieties of peaches, ripening at different seasons, with particular reference to the development of the embryo as related to development of the nucellus and integuments and the fleshy and stony pericarp.

Procedure

Five varieties of peaches of various dates of fruit ripening were chosen, namely: Greensboro, ripening 91 days after full bloom; Triumph, 100 days; Carman, 113 days; Elberta, 124 days; and Chili, 144 days. Random samples of 5 to 10 fruits were gathered every other day throughout the growing season from full bloom to fruit ripening, extending from May 4 to September 25 in 1933 totalling over 300 collections and over 5,000 individual measurements. Development of collected samples was checked by chilling in a refrigerator at 35 degrees F. It was possible by this means to extend the period for examination by 2 or 3 days.

Measurements were made of total length along the central axis, using a Vernier caliper for large measurements, and a 1/10 mm. rule and a dissecting microscope for smaller ones. Although length may be a less exact measurement than volume and dry weight, it is closely related to volume and is well suited to comparative measurements of the parts included in this discussion and to the demands of large numbers and rapid measurement.

Results

The comparative development of fleshy and stony pericarp, nucellus and integuments, and embryo are given in Table I, while Fig. 1 presents graphically the principal features of this study. The abruptness and exactness of the changes from one period of development to another and the almost identical nature of some of the relationships in a matter so complex as growth are striking. With measurements at intervals less frequent than every other day some of the most significant facts might easily be overlooked. Measurements at weekly intervals or greater might conceivably straddle the points of greatest significance.

Fleshy pericarp development:—There are three periods of pericarp development, namely, a period of rapid increase (Stage I), a period of delayed increase (Stage II), and a second period of rapid increase (Stage III). The duration of the first period is similar in all varieties, and the change to the period of delayed growth (Stage II) is abrupt. In 1933, this date was June 23 for Greensboro, June 25 for Carman, June 26 for Elberta, and June 23 for Chili. The size attained during this first period of rapid pericarp development varies, namely, 33.5 mm. for Greensboro, 29.0 mm. for Triumph, 35.1 mm. for Carman, 43.0 mm. for Elberta, and 35.8 mm. for Chili; showing that the duration of the period is independent of the rate of growth and the size attained during this period.

The duration of the period of delayed increase (Stage II) is correlated directly with the date of fruit ripening. That is, this period is shortest in the earliest ripening variety and longest in the latest, namely, 5 days for Greensboro, 10 for Carman, 35 for Elberta, and 42 for Chili. Blake also noted this relationship (2), stating, "The stage subject to the greatest modification is Stage 2. This may be

only 1 or 2 weeks in the case of the early clingstone varieties, or it may be 4 to 7 weeks in the case of the late-ripening varieties."

The second period of rapid pericarp increase (Stage III) is less rapid than the first and continues until the flesh is soft, when it abruptly ceases. The size of the fruit when soft ripe, measured in length, was 47.0 mm. for Greensboro, 42.0 mm. for Triumph, 55.5 mm. for Carman, 69.0 mm. for Elberta, and 64.0 for Chili.

The effect of rainfall and temperature variations may be seen in the zigzag nature of the curves, but the relationships throughout the season are not altered. Corroborative evidence is found in the data published by Connors (6) for the season of 1918, which, when charted, approach these curves closely. Moreover, the curves presented by Lilleland (15, 16) when not smoothed, agree still more closely.

Stony pericarp development:—The stony pericarp begins to differentiate during the early part of the first stage of rapid fruit increase, but it does not begin to harden until the fleshy pericarp has entered the stage of retarded increase (Stage II). In 1933, initiation of stone hardening, which begins at the distal end and along the dorsal side, was almost simultaneous for all five varieties. In Greensboro, hardening began 53 days after full bloom, in Triumph 53, in Carman 55, in Elberta 53, and in Chili 55. The rapidity of hardening throughout the stony pericarp varied, however, progress being most rapid in the earliest ripening varieties. Within 8 days from the time hardening began, Greensboro stony pericarp was designated hard throughout; while at the same time the stony pericarp of Triumph was designated as less hard than Greensboro and in decreasing order through Carman, Elberta, and Chili. This is interesting in view of the fact that in early-ripening varieties the embryo aborts and that food materials in the stony pericarp are depleted during later growth of the fleshy pericarp and the seed, as shown by Lott (17).

Nucellus and integument development:—As in the case of the cherry (20), and the apricot (15) and as noted for the peach (2, 3, 7, 9, 13, 16, 17), the nucellus and integuments make rapid increase, beginning about the time of full bloom, and quickly reach maximum or nearly maximum size. In all five varieties, regardless of season of ripening and of size of nucellus and integuments, the dates of cessation of rapid growth were close, namely: Greensboro, 18.2 mm, June 23; Triumph, 15 mm. June 20; Carman, 17.8 mm, June 23; Elberta, 20.5 mm, June 25; and Chili, 16.0 mm, June 23. In fact, the dates are so nearly identical that they suggest that an even closer degree of uniformity would be found if single fruits could be used for measurement throughout the season rather than random samples. Here again the duration of the period of rapid growth is independent of the rate of growth and the size attained during that period. Subsequently, in seeds in which the embryo failed to develop, the nucellus collapsed, giving the characteristic abortive seed with shrivelled integuments.

On the same date the degree of browning of the integuments varied with the season of fruit ripening; that is, 126 days after full bloom the integuments of Carman were brown and shrivelled, those of Belle of Georgia were browning but not shrivelled, those of Early Craw-

ford were beginning to brown, and those of Champion and Elberta were whitish, indicating, as with the stony pericarp, a progressively later differentiation correlated with fruit ripening.

Embryo development:—The embryo, located near the distal end of the erect anatropous ovule, is arrested in development until 49 to 50 days after full bloom. That is, the embryo had reached only 0.6 mm. in size 50 days after full bloom in Greensboro, 0.8 mm. in Triumph, 0.7 mm. in Carman, 0.6 mm. in Elberta, and 0.5 mm. in Chili. Because of its small size during the time that the nucellus and integuments are reaching maximum size, the embryo may be easily overlooked (8).

At this time the embryo begins a rapid enlargement, reaching maximum size in 29 to 31 days, namely, 81 days after full bloom in Greensboro, 78 days in Triumph, 81 days in Carman, 81 days in Elberta, and 80 days for Chili. This almost identical growth period for the embryo of all five varieties regardless of the season of fruit ripening is one of the striking findings of this study. Again, the duration of the period of growth seems independent of the ultimate size and growth rate of the embryo for the variety. Thus, the embryos of Greensboro reached a maximum of 16.5 mm, of Triumph 14.0 mm, of

TABLE I—SUMMARY OF COMPARATIVE DEVELOPMENT OF FLESHY PERICARP, STONY PERICARP, NUCELLUS AND INTEGUMENTS, AND EMBRYO OF GREENSBORO, TRIUMPH, CARMAN, ELBERTA AND CHILI PEACHES THROUGHOUT THE SEASON

Variety	Days from Full Bloom to Completion of Stage of Development			Size at Completion of Stage of Development (Length in Mm)		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
			Fleshy Pericarp			
Greensboro....	50	55	91	33.5	34.0	47.0
Triumph......	49	58	100	29.0	30.0	42.0
Carman.......	52	62	113	35.1	35.4	55.5
Elberta.......	53	88	124	43.0	47.0	69.0
Chili..........	50	92	144	35.8	40.0	64.0

Stony Pericarp

Variety	Days from Full Bloom to Initial Hardening of Pit	Degree of Hardness 61 Days After Full Bloom	Maximum Size (53 Days After Full Bloom) (Length in Mm)
Greensboro....	53	Hard	32.0
Triumph......	53	Softer than Greensboro at 61 days	26.5
Carman.......	55	Softer than Triumph at 61 days	32.0
Elberta.......	53	Softer than Carman at 61 days	39.0
Chili..........	55	Softer than Elberta at 61 days	32.0

Nucellus and Integuments

Variety	Days from Full Bloom to Maximum Enlargement	Maximum Size (Length in Mm)	Size and Condition at Fruit Ripening (Length in Mm)
Greensboro....	50 No further enlargement	18.2	17.0 (Shrivelled)
Triumph......	47 No further enlargement	15.0	14.2 (Shrivelled)
Carman	50 No further enlargement	17.8	17.0 (Shrivelled)
Elberta.......	53 No further enlargement	20.5	21.0 (Plump)
Chili..........	50 No further enlargement	16.0	16.4 (Plump)

Embryo

Variety	Days from Full Bloom to Beginning of Rapid Embryo Development	Days from Full Bloom to Attainment of Maximum Size	Days from Full Bloom to Fruit Ripening	Size 50 Days After Full Bloom (Length Mm)	Maximum Size (Length Mm)	Size and Condition at Fruit Ripening (Length Mm)
Greensboro....	50	81	91	0.6	16.5	16.5 (Many small and abortive)
Triumph......	49	78	100	0.8	14.0	14.0 (Many small and abortive)
Carman.......	50	81	113	0.7	18.0	18.0 (Many small and abortive)
Elberta.......	49	80	124	0.6	20.0	20.0 (Sound, plump)
Chili.........	50	80	144	0.6	16.0	16.0 (Sound, plump)

Carman 18.0 mm, of Elberta 20.0 mm, and of Chili 16.0 mm. This rapid embryo growth accounts for the increase in dry weight of the seed as reported by Lott (17) and by Lilleland (16).

As in the case of the cherry, embryos of early-ripening peach varieties fail to develop fully, as reported by Chandler (5), Connors (6), and Sakaguchi (19). The indications from Table II are in agreement with the findings of Connors (6) that varieties which ripen in less than 80 days from pollination have no viable seed, varieties ripening 85 to 90 days have 15 per cent, and those ripening later have 50 to 85 per cent viable seed.

Correlation of growth:—The correlation of the growth of embryo, nucellus and integuments, and pericarp is similar to that for the cherry (20), with the difference that a longer growing season for the peach and larger size provide conditions more favorable to study.

Dividing growth into three stages based on the growth of the pericarp (6), namely, (Stage I) rapid, (Stage II) delayed, and (Stage III) rapid, the growth of the nucellus and integuments during Stage

I parallel the rapid growth of the pericarp and cease abruptly at the same time, while the embryo is arrested in development throughout this period. At the beginning of Stage II (retarded development of the pericarp), the stony pericarp differentiates and hardens throughout, and the nucellus and integuments enter a period of retarded development, while the embryo begins a rapid enlargement. The embryo may or may not reach maximum size during this period, depending on the variety.

TABLE II—RELATION BETWEEN RIPENING OF FRUIT AND ABORTION OF EMBRYO

Variety	Days Full Bloom to Fruit Ripening	Condition of Integuments 118 Days After Full Bloom
Maule Early	75	Brown, shrivelled
Vainqueur	80	Brown, shrivelled
Early Victor	80	Brown, shrivelled
Schumaker	81	Brown, shrivelling
May Lee	85	Browning, shrivelling
Mikado	87	Brown, shrivelled
Canada	89	Whitish brown, shrivelling
Arp	95	Whitish, shrivelling
Golden Jubilee	107	White, no shrivelling
Delicious	111	White, no shrivelling
Waddell	111	Slightly brown, no shrivelling
Alexander Crosby	111	Slightly brown, no shrivelling
Morellone	111	White, no shrivelling
Rochester	111	White, no shrivelling
St. John	113	Slight browning, no shrivelling
Foster	114	Browning, irregularly
Carman	114	Browning, shrivelling
Valiant	114	White, no shrivelling
Mountain Rose	114	Variable, some white, some brown
Veteran	114	Shrivelled, variable
Troth	120	White, some slightly shrivelled
Early Crawford	124	White, no shrivelling
Champion	126	White, no shrivelling
Belle of Georgia	126	White, no shrivelling
Elberta	134	White, no shrivelling
Chili	144	White, no shrivelling

The duration of Stage I (rapid pericarp development) is nearly identical for all varieties for development of pericarp, nucellus and integuments, and embryo. If a vertical line is projected on the growth curves of these varieties 50 days after full bloom (Fig. 1), it will pass through, or near, the point of initiation of rapid embryo development, retarded nucellus and integument increase, and retarded pericarp increase. In other words, in all five varieties studied, the abrupt change from rapid to delayed pericarp and nucellus and integument increase is correlated with the abrupt initiation of rapid embryo development—regardless of the time of fruit ripening. Whether the increase in embryo development is due to the retarded development of pericarp and nucellus and integuments, or *vice versa,* is a question similar to that presented by the cherry (20) and as yet unanswered.

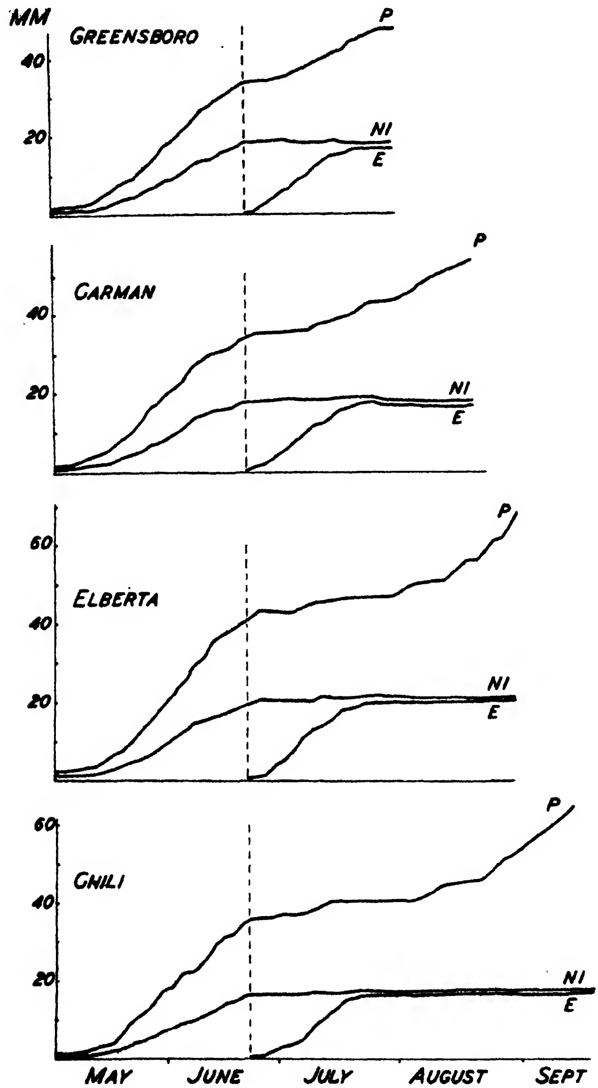

FIG. 1.—Growth curves from full bloom to fruit ripening of pericarp (P), nucellus and integuments (NI) and embryo (E) of four varieties of peaches ripening at different seasons.

Note the nearly identical time of abrupt change from arrested to rapid embryo increase (represented by vertical dotted line) for all varieties independent of season of fruit ripening, and the correlated abrupt arrest in increase of nucellus and integuments and pericarp. Note also the nearly identical duration of periods of rapid embryo increase for all varieties, as contrasted with the differing rates of pericarp development (to right of dotted line). Other comments in the text.

The duration of Stage II (delayed pericarp development) varies with the variety, the earliest ripening varieties having the shortest period. Correlated with this is the fact that early-ripening varieties tend to have abortive embryos, as with the cherry (20). In early-ripening varieties, Stage II (delayed pericarp development) may give way to Stage III (rapid pericarp development) before the embryo has completed its growth. Whether the abortion of the embryo leads to the initiation of Stage III, or whether the initiation of Stage III results in the abortion of the embryo is a question as yet unanswered. It is significant, however, that abortive peach embryos have been cultured artificially by the author during the season of 1933 in a manner similar to that used for the cherry (20). It should also be pointed out that, although the stony pericarp began to harden at about the same time for the five varieties considered, the hardening proceeded more rapidly in the earlier ripening than in the later ripening varieties. It has been shown (20) for the cherry that the earliest ripening fruits of a given variety have both the smallest embryos and the smallest development of nucellus and integuments.

During Stage III (rapid pericarp development) the pericarp reaches maximum size, ceasing its enlargement when the fruit softens.

Discussion

The frequency of the measurements throughout the season give a more complete record of the growth of the pericarp, nucellus and integuments, and embryo than has heretofore been placed on record. The close similarity of certain portions of the curves for all varieties regardless of season of fruit ripening is striking. The periods of embryo development, for example, tend to be constant throughout, the duration of these periods being almost identical, except as the embryos of early-ripening varieties tend to be abortive.

On the other hand, the duration of growth periods of the pericarp differ widely for different varieties, the earliest ripening varieties having the shortest period of delayed pericarp development (Stage II), and the latest ripening varieties having the longest period. The point is plainly illustrated that periods of growth activity may or may not be parallel and may even be opposing for different portions of the plant at the same time. The growth of the pericarp and of the nucellus and integuments is nearly parallel during the first stage of rapid pericarp development (Stage I), except that the nucellus and integuments reach nearly maximum size while the pericarp does not. During this period the embryo is arrested. At the identical time that the embryo begins its most active growth, the nucellus and integuments and pericarp are arrested (Stage II).

As Goldschmidt (14) has pointed out, the successful continuation of individual development is dependent upon the orderly interweaving of developmental processes and as soon as gene changes occur which upset or interfere with this orderly development so as to make the individual unstable, the step in developmental evolution is broken. This situation is apparent in the peach as here reported and for the

cherry (20) in which the growth periods of pericarp and of embryo of early ripening varieties are such as to interfere with the survival of early-ripening characters, except for the fact that they are perpetuated by such horticultural methods as budding and grafting. In other words, natural evolution is checked in the direction of early-ripening fruit characters. The importance of these facts to plant breeders and geneticists is apparent and needs no further discussion.

In addition, certain aspects of a physiological nature are suggested by this relation betwen embryo development and the development of the seed and fruit parts. It would be interesting to know, for example, the relationships between these and other parts of the plant involving other functions, such as primary and secondary growth in the plant body, dropping of fruit, fruit bud formation, and the like. The possibilities from a critical study of such relationships are highly suggestive.

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Relation of Pruning and Thinning to Fruit Size and Yield of Paloro Peaches

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IN the fall of 1930, some peach pruning tests were undertaken at Shafter, California. In this locality, 3- and 4-year-old trees make tremendous vegetative growth when pruned heavily. Annual growth of 6 feet is common in commercial orchards where heavy pruning is practiced. Young trees may be unfruitful if heavily pruned. Mature trees are very fruitful and are pruned and thinned severely in order to maintain vigor for the production of heavy crops of choice fruit.

The objects of these tests were (a) to study the response of young trees to varying degrees of pruning and (b) to study the relationship of leaf area to size and development of the fruit.

The treatments were as follows:

1. No pruning except the removal of dead and broken limbs: none.
2. Four groups of trees which, in addition to having dead and broken limbs removed, had half the growth thinned out and the remaining shoots cut back varying amounts, as follows:

A. Remaining shoots not cut back:—light pruning.
B. Remaining shoots cut back 1/4:—medium pruning.
C. Remaining shoots cut back 1/2:—Medium heavy pruning.
D. Remaining shoots cut back 3/4:—heavy pruning.

The trees used were uniform healthy 3-year-old Paloro worked on Point Loma understocks, with the exception of the heavily pruned trees, of which four were worked on Waldo, three on Luckens, and three on Elberta understocks. Waldo and Luckens are very similar to Point Loma, all being of the Honey type.

The circumference of the trunk of each tree was measured each winter 6 inches above the bud union. The prunings removed were weighed annually, the fruits were thinned to uniform distances the first year but to graded distances the next 2 years, the fruits obtained from each tree were counted and weighed, and the amount of new terminal growth was measured on five representative trees 2 years.

Results

The response of the trees in 1931, the fourth season was very striking. The unpruned trees with a heavy set of fruit showed a marked slowing up at all growing points, the shoots were very short, the crop was heavy, and the fruit was small. Shoots of the heavily pruned trees were long, the crop was light, and the fruit was very large. On all trees the growth increased with the heavy pruning but total fruit production decreased.

The differences were so striking by mid-season of 1931 that five healthy trees, one from each group and of almost identical trunk circumference, were tagged for some detailed measurements which were carried on during the summers of 1931 and 1932. The data

TABLE I—EFFECT OF PRUNING AND THINNING ON FRUITING AND VEGETATIVE HABITS OF PALORO PEACH TREES, 1932, 5 TREES IN TEST.

Pruning Treatment	Number of Shoots	Linear Growth (Inches)	Average Length per Shoot (Inches)	Trunk Cir. Increase (Inches)	Number Fruit Thinned	Number Fruit Ripe	Weight of Fruit (Pounds)	Average Weight per Fruit (Pounds)	Number Fruit Set
None..........	12,893	18,421	1.44	1.81	2,042	998	137.1	.14	3,040
Light..........	4,940	22,862	4.62	1.81	1,656	631	152.4	.24	2,287
Medium.......	7,698	27,809	3.62	1.46	1,249	818	181.3	.22	2,067
Medium heavy.	4,559	38,918	8.50	2.76	563	515	146.8	.28	1,078
Heavy.........	4,132	41,004	9.90	2.56	375	375	109.5	.29	750

TABLE II—EFFECT OF PRUNING AND THINNING ON FOLIAGE, 1932, 5 TREES IN TEST

Pruning Treatments	Number Leaves Measured	Average Length (Inches)	Area per Leaf (Sq. In.)	Number Leaves per Tree	Area per Tree (Sq. In.)	Leaves per Ripe Fruit	Leaves per Fruit Set
None................	337	4.17	2.7	40,510	109,500	40.5	13.3
Light................	303	5.00	3.6	64,000	228,000	101.4	28.0
Medium.............	318	4.65	3.2	69,500	222,000	85.0	33.5
Medium heavy.......	296	5.81	3.8	58,410	220,800	113.4	54.3
Heavy...............	226	6.02	4.7	53,380	248,700	142.4	71.2

TABLE III—THE EFFECT OF PRUNING ON FRUIT PRODUCTION, 1931–1933*

Pruning Treatments	Number of Trees	Trunk Cir. Increase (Inches)	Pruning Wts. per Tree (Pounds)	Number Fruits Set	Number Fruits Thinned	Number Ripe Fruits	Wt. of Fruit per Tree (Pounds)	Average Wt. per Fruit (Pounds)
None...........	10	4.25±.26	12.6±1.0	7307±381	4996±307	2312±93.7	387±22.2	.17±.006
Light...........	15	5.12±.12	47.8±2.0	5568±242	3860±165	1650±69.7	342±16.6	.21±.003
Medium.........	6	5.04±.33	60.3±3.6	4634±258	3013±164	1621±107.7	352±23.7	.22±.005
Medium heavy ..	8	6.06±.29	73.8±4.7	2178±159	1225±106	953±56.2	233±18.4	.24±.006
Heavy..........	10	7.95±.26	118.4±8.8	926± 61	411± 40	515±26.4	148± 9.5	.29±.007

*Data expressed as average per tree for the total period.

for 1932 appears in Table I. Total linear growth for the year was obtained by measuring every growing point showing development of ¼ inch and over. The new growth from the growing point to the mother branch was designated a "shoot" whether it was the entire year's growth or just a lateral from an extra vigorous branched shoot.

During 1931, the first year of the test, the shoots of the unpruned tree averaged 0.8 inch in length and the fruit was very small but over abundant. Shoots of the heavily pruned trees averaged 13.3 inches long, the crop was light and the fruit very large. It was the desire to produce crops of fairly good-sized fruit on all the trees, so for the next 2 years the fruits, instead of being thinned alike on all trees (4 to 6 inches on the shoot) were thinned as follows: none, 18 to 24 inches; light pruning, 11 to 14 inches; medium pruning, 7 to 10 inches; medium heavy pruning, 4 to 6 inches; heavy pruning, 2 to 3 inches. This graded thinning saved a considerable breakage in the unpruned trees and stimulated in them a wave of vegetative growth, new growing shoots appearing all over the trees. While the graduated thinning distances did not equalize the growth for trees of all groups, it lessened the extremes in both fruit and branch growth. Shoots from unpruned trees increased from .8 inch to 1.44 inches, while those of the heavily pruned tree decreased from 13.3 to 9.9 inches. It will be noted (Table I) that heavy pruning, even with graduated thinning distances, reduced the number of shoots by about two-thirds, but the average length per shoot on the heavily pruned trees was 9.9 inches as contrasted with 1.44 inches for the non-pruned trees. Thus the total linear growth on the heavily pruned trees was nearly 2¼ times greater.

Effect of Pruning on Production

The amount of fruit produced was greatly reduced by the heavy pruning. This was true even when thinning was somewhat graduated to the severity of the pruning. The lightly pruned and non-pruned trees set, respectively, three and four times as many fruits as the heavily pruned trees and had two-thirds of the fruit set removed by thinning. The largest amount of fruit was produced by the medium pruned trees. More fruits were left on the non-pruned trees, but the fruit was small. Extremes in fruit size were obtained on the non-pruned and heavily pruned trees. Much of this difference can undoubtedly be explained by the effect of pruning and thinning on leaf area.

Effect of Pruning on Leaf Area

In the late fall of 1932, just as the leaves were beginning to drop, all leaves were collected from one major limb and counted. The total for the tree was prorated on the basis of the new growth of this limb, since the new growth for this limb and that of the whole tree had been measured. About 300 leaves were taken from different sections of each tree and their lengths measured, using typical shoots as units.

A sample of 10 leaves of average length was picked from each tree, measured with a planimeter and the average area was considered in calculating the average for the tree.

It will be seen from Table II that all pruned trees had over twice as much total leaf area as the non-pruned trees. The more lightly pruned trees had more leaves than the heavily pruned ones, but the latter had larger leaves. The leaf surface of the heavily pruned trees was nearly sufficient to produce fruit of commercial size had the fruit not been thinned. Thus the leaves on the more heavily pruned trees ranged from 50 to 70 leaves per fruit set, while after thinning the ratio was 113 to 142 leaves per fruit. It is not surprising that with heavy pruning and thinning the fruits were large but the crop was reduced. The fruit on the non-pruned trees was small, even though it was thinned to 40 leaves per fruit. It should be noted, however, that these trees set a heavy crop and there was undoubtedly a heavy drain on the tree reserves before the fruits were thinned. The heavier thinning of the fruit did not result in as good growth or yield as where moderate pruning was accompanied by moderate thinning.

The total yield obtained during the 3-year period of these tests (1931–1933) (Table III) indicates that the more lightly pruned trees have been the most productive. Trees that have received medium light pruning and thinning produced about 60 per cent more fruit of good commercial size than similar trees receiving medium heavy to heavy pruning.

These tests show clearly that a proper balance between growth and production can be maintained by pruning and thinning at fruiting age. Vegetative growth can be quickly checked by less pruning and thinning if frost or other factors do not interfere with the set of fruit. Unpruned trees bearing a heavy crop slow up tremendously in growth. They have fewer leaves and less leaf area due to the smaller size of the leaves and the shorter length of the growing shoots. In order to obtain greater yields, thinning of fruits alone did not produce fruit of good commercial size on the Paloro variety. The competition of the heavy set of fruit checks size of foliage and shoot growth. The greater the vegetative growth within the limits of this test, the larger the leaves and fruit. However, more fruit of commercial grade is produced with medium pruning on trees 3 to 7 years of age. From an economic standpoint the cheapest thinning of the fruit is done by pruning. Hand thinning of the fruit is a necessary accompaniment to adjust the number of fruits to the leaf area of the tree.

Certain Advantages of Early Thinning of Elberta

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Abstract

Complete details of this work will be published in a bulletin from the Ohio Experiment Station.

THE experiments which form the basis of this brief report were conducted at Wooster in 1931 and 1932. They have shown certain effects of thinning both (a) in a year when a heavy set of fruit followed a year in which the trees did not bear a crop, (b) in the succeeding year, when the set of fruit on the trees varied strikingly due to the previous year's treatment. The results concerning the effects on the succeeding crop are associated with the fact that each tree receiving a certain thinning treatment in the first year of the work received a corresponding treatment the next year. During the two consecutive years, the same Elberta tree was left unthinned and 12 others were thinned early or late to guide spacings of 4, 6, or 8 inches. As used here, early thinning refers to thinning done near the middle of June (just before or soon after the start of the "June drop"), and late thinning refers to that done near mid-July (soon after most of the June drop peaches had fallen).

Effect on yield and size in a year (1931) when the set of fruit was heavy:—Very early thinning, by causing the retention of a certain number of desirably located fruits which otherwise would have dropped, resulted in less reduction in yield than later thinning. All thinning treatments reduced the yield below that of the unthinned tree.

The percentage and quantity of largest-sized fruit (2¼ inch up) increased with early thinning (a) when the guide spacing was increased from 4 to 6 to 8 inches, (b) when the percentage of peaches removed per tree was increased. Late thinning did not result in a corresponding increase. Hence early thinning was the most influential factor determining large size of fruit.

Both early and late thinning decreased the percentage of fruit in the smallest sizes. Early thinning reduced the percentage of small peaches more than did late thinning.

The effect of early thinning on size of fruit was sufficient, in a number of cases, to result in fewer peaches per bushel (thus larger size) and also a higher yield per tree than from late thinning.

Effect on yield and size of fruit from thinning (1932) following corresponding treatments the year previous:—Due chiefly to the previous year's thinning treatment, the trees thinned early produced twice as much fruit, in the second year of the work, as those thinned late and four times as much as the unthinned tree.

The lighter the yield per tree the higher was the percentage of largest-sized fruit (2¼ inch up) but, because of the larger yield per tree associated with the cumulative or residual influence from the

previous year's treatment, the early thinned trees produced more large fruit than the late thinned, and the late thinned outyielded the unthinned tree.

In no case was size of fruit increased sufficiently to result of itself in the striking increase in yield that accompanied the early thinning.

Receipts:—In 1931, a year when the market demand was critical, because of the larger size of fruit a greater amount was sold and at a higher price from each thinned tree than from the higher yielding unthinned tree. The early thinning, although involving the most expense, about doubled the receipts over no thinning. With late thinning in 1931, when the set of fruit was heavy, (a) the receipts per tree were only slightly more than from no thinning; (b) size was not increased sufficiently to offset the reduction in yield when compared with no thinning; (c) the smaller expense of late thinning did not compensate for the higher returns due to the greater amount of largest-sized fruit which resulted from early thinning.

In 1932, due to the higher yield and greater amount of largest-sized fruit which occurred as a result of the influence of the previous year's thinning treatment, early thinning was more than four times as profitable as no thinning and twice as profitable as late thinning.

Fruit Growth and Temperature Relationship in the Date Palm

By D. W. Albert and R. H. Hilgeman, *University of Arizona, Tucson, Ariz.*

FRUIT development of the date palm (*Phoenix dactylifera* L.) can be divided into four quite distinct stages, namely, growth of the spathe, growth of the flower stalk, growth of the fruit, and ripening of the fruit. The first stage may be arbitrarily set from the time the buds start to elongate until the spathes burst, at which time the flowers are receptive. During the first few weeks following pollination, growth is confined largely to the flower stalk. After the stalk has reached approximately its full length, the dates increase in size rapidly until they reach a maximum length and diameter. During this period the seed also reaches maximum size and apparent maturity. The final stage is characterized by the rapid accumulation of sugar, precipitation of tannin, change in color and softening of the tissue without further increase in size.

Results of bud and spathe growth have been previously reported (1) but since this paper is a continuation of that report, a very brief summary of it is presented here.

TABLE I—Growth (Length in Centimeters) of Upper and Lower Buds of 1932 Flowering Cycle

Date Measured	May 14	June 25	Aug. 6	Sept. 17	Nov. 2	Dec. 21	Feb. 1	Mar. 7	May 7
First 3 buds.......	.52	.64	1.14	1.21	2.58	5.58	8.82	27.43	103.5
Last 3 buds.......	.23	.31	.44	.49	2.45	10.17	20.30	97.43	164.5
Average for all buds	.41	.52	.76	.85	2.53	7.54	15.04	60.83	136.7

Table I shows the length of spathes at definite periods during the year 1931–32 of nine Rhars palms of uniform size, 28 to 32 years old, which were dissected over a period of 12 months. The number of flower buds produced by the different palms varied from 12 to 23. The first three buds of the following cycle referred to in Table I are the buds immediately following the 1931 cycle, and are therefore located farthest from the apex of the main axis of the palm. These constitute the basal end of the flowering cycle.

Up to September 17, the buds nearest the base of the cycle had made the greatest growth. On November 2, all buds were approximately the same size, showing that the rate of growth of the upper buds had been accelerated. After November 2, the buds toward the upper end of the cycle continued their rapid growth and flowered earlier than did the basal buds. The first three spathes opened during the last week in March and by May 7 all spathes had burst. The measurements of May 7 show the length of the spathes at the time they opened.

The present paper presents the results of fruit growth measurements and possible correlations of the growth curves derived therefrom with temperature conditions prevailing during the period of study.

Normal blossoming in the date palm extends over a period of from 3 to 6 weeks. Despite this, all clusters mature fruit at approximately the same time. All of the fruit in a cluster does not ripen at once. Ripening continues over a period of from 4 to 8 weeks, depending upon the variety and weather conditions.

No attempt was made to measure the fruit until after the fruit stalks had attained maximum growth and the dates were at least one centimeter in length. Measurements were made on fruits of three

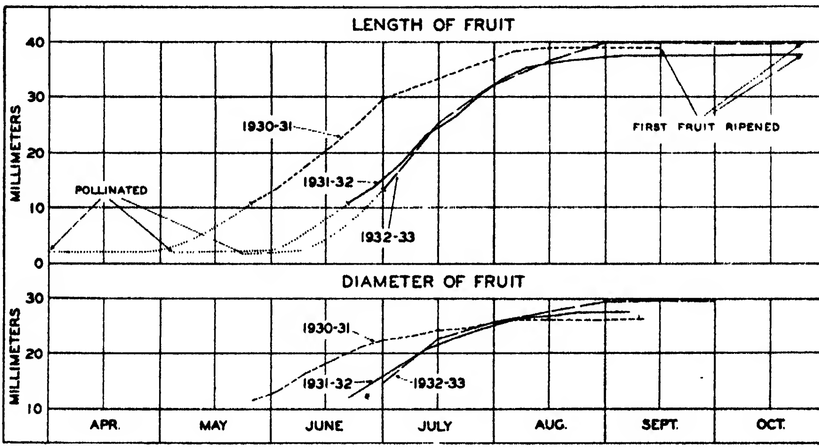

FIG. 1. Growth curve of Maktoom fruit.

varieties, Hayany, Deglet Noor and Maktoom, growing in the Salt River Valley at the University Date Garden near Tempe, Arizona. Fruits selected from the upper, middle, and lower sections of individual strands located in different parts of the cluster were measured weekly during 1931, 1932, 1933. All dates were measured at their greatest length and diameter with a vernier caliper, read to the nearest half millimeter.

Fig. 1 shows the growth curve and dates of blossoming and ripening of the Maktoom variety covering the 3-year period. These curves are typical of each of the varieties studied and, no doubt, of other varieties grown under similar conditions. During the period in which the fruit stalk is developing, the growth of fruit is very slow. When the fruit stalk completes its elongation, the fruit begins a very rapid growth. After the dates have attained their full size, there is a slight shrinkage as they approach full maturity. Early maturing varieties, as the Hayany, start to ripen soon after the fruit reaches maximum size. The ripening process of later maturing varieties, as Maktoom and Deglet Noor, develops more slowly.

Fig. 2 shows the mean monthly temperatures for the 1930–31, 1931–32, and 1932–33 fruiting seasons. These data were compiled from U. S. Weather Bureau records obtained at the University Date Garden station. In addition to the official maximum and minimum readings a recording hygrothermograph has been maintained for the past several years.

The fruit developing season for the date palm, as the term is used in this paper, extends from the time the spathe buds start a pronounced growth until the fruit has ripened.

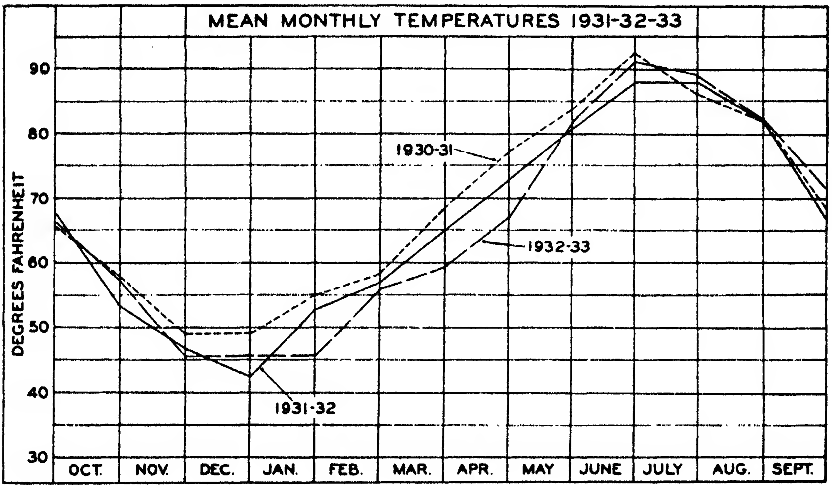

FIG. 2. Mean monthly temperature for 1930–31, 1931–32, 1932–33 fruiting seasons.

The comparatively warm winter, spring, and early summer of 1930–31 is reflected in the early blossoming and ripening of that year. The 1931–32 season was colder during the entire period of spathe and fruit growth. Both blossoming and ripening were delayed. The uniformly cold winter and spring of 1932–33 was followed by quite late blossoming. High temperatures in late summer and fall, however, brought the fruit to maturity on approximately the same date as in the previous year.

These data indicate that winter temperatures have a direct influence upon spathe development and subsequent time of blossoming. Temperatures occurring after blossoming apparently have more effect on the time of ripening than does the date of blossoming.

In order to correlate this in a more concrete form the problem was studied from several angles, such as (a) average maximum temperatures, (b) average minimum temperatures, (c) average relative humidity, and (d) total heat units. Correlations of maximum and minimum temperatures and relative humidity gave inconclusive results. There was however, a slight indication in 1931 that the rate

of growth was retarded by extremely high temperatures. During July of that year the first 21 days had an average maximum temperature of 109.3 degrees F. It will be noticed in Fig. 1 that the growth curve has a tendency to flatten during that period. The growth curve for the Hayany showed a more pronounced loss in rate of growth but the Deglet Noor showed about the same as the Maktoom. The mean daily humidity for that period was 48.5 which may also have been a factor in retarding growth.

Heat units were calculated upon the mean daily temperatures above 50 degrees F. The work of Vinson (2) and Mason (3), established the minimum temperature permitting growth in the date palm at approximately 50 degrees F. Heat units were calculated for the 3 seasons beginning with the time of blossoming and extending to the time ripening had started. These calculations are presented in Table II.

TABLE II—SUMMARY OF HEAT UNITS REQUIRED TO MATURE FRUIT

	Maktoom		
Year	1931	1932	1933
Date pollinated	April 1	May 3	May 20
Date ripened	Sept. 15	Oct. 25	Oct. 25
Summation of heat units	5354	5366	5274
	Deglet Noor		
Year	1931	1932	1933
Date pollinated	Mar. 17	April 9	April 22
Date ripened	Sept. 10	Oct. 10	Oct. 7
Summation of heat units	5372	5388	5198
	Hayany		
Year	1931	1932	1933
Date pollinated	Mar. 23	April 20	May 5
Date ripened	Aug. 15	Sept. 6	Sept. 6
Summation of heat units	4327	4204	4170

The Hayany, an early maturing variety, required approximately 4200 units of heat, while the Maktoom and Deglet Noor, both late ripening varieties, required about 5300 units. It is noteworthy that approximately the same number of calculated heat units were required to mature the fruit each of the three years altho the time of blossoming and of maturity and seasonal temperature conditions varied markedly.

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The Relationship of Ripening Temperatures to the Rate of Softening, Texture and Flavor of Kieffer Pears

By J. M. Lutz, C. W. Culpepper, and H. H. Moon, *U. S. Department of Agriculture, Washington, D. C.*

IN spite of its reputed poor quality, the Kieffer pear is grown extensively in the eastern and southern States, largely because of its productiveness and blight resistance. Experimental work was started in 1932 in an attempt to determine the factors which might improve the quality of this fruit.

Materials and General Methods

The fruit used in 1932 consisted of five pickings made at Beltsville, Maryland, at approximately 10-day intervals, the first being made on September 16 and the last on October 25. In 1933, four pickings were made at approximately 10-day intervals on fruit grown at Arlington Farm, Virginia. In addition fruit was secured from State College, Mississippi, South Haven, Michigan, Lockport, New York, College Park, Maryland and Beltsville, Maryland. The first picking at Arlington Farm was made on August 18 and the last on September 21.

All pickings were subjected to ripening temperatures of 60, 70, and 80 degrees F and lots from nearly all were ripened at 50 degrees. In addition, 32, 40, 65, 90, and 100 degrees were used with several lots. Firmness was determined, at intervals during the ripening period, by means of a pressure tester using a plunger 5/16 inch in diameter (3).

Results

Influence of time of harvesting:—The time of harvesting seemed to have little influence on the quality of the Beltsville fruit in 1932, although the fruit of the first picking was not quite equal to that of subsequent pickings. In 1933, the intermediate pickings of Arlington fruit were of somewhat higher quality than either the first or last pickings.

Influence of temperature on rate of softening:—Figs. 1 and 2 illustrate the influence of temperature on changes in firmness of pears grown at Beltsville, which were harvested September 25, 1933. It is clear that the most rapid softening occurred at 65 degrees F, followed closely by 60 degrees. The rate of softening decreased as the temperature varied above or below 65 degrees.

In Figs. 3 and 4 are shown the changes in firmness of the New York grown pears as influenced by temperature. Here, the most rapid softening was at 60 degrees F. No trial at 65 degrees was made with this fruit.

The relationship of temperature to rate of softening, as shown in Figs. 1 to 4 inclusive, is typical of the results obtained with all lots of fruit used in these experiments.

Influence of ripening temperature on quality:—The quality attained by Kieffer pears seemed to be determined largely by the temperature at which they were ripened. This variety ripened at 60 degrees F to a pressure test of 3 to 4 pounds was nearly always of considerably better quality in both texture and flavor than is usually considered

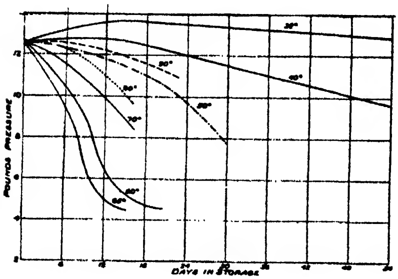

FIG. 1. Changes in firmness of Kieffer pears (Beltsville 1933) as influenced by temperature.

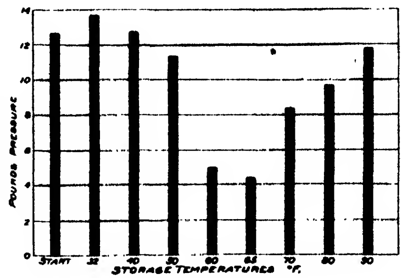

FIG. 2. Firmness of Kieffer pears (Beltsville 1933) after 16 days storage at various temperatures.

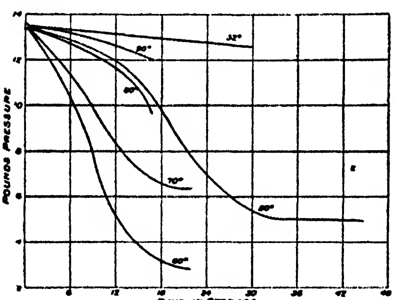

FIG. 3. Changes in firmness of Kieffer pears (New York 1933) as influenced by temperature.

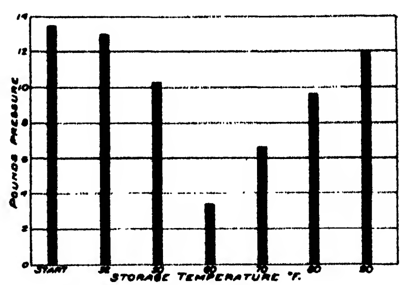

FIG. 4. Firmness of Kieffer pears (New York 1933) after 17 days storage at various temperatures.

possible. Pears ripened at 65 degrees were equal or nearly equal to those ripened at 60 degrees F. Kieffer pears ripened at 70 degrees were about equal in quality to that ordinarily expected of this variety and were always markedly inferior in texture and flavor to fruit ripened at 60 degrees. The development of flavor decreased progressively as the temperature was increased above 65 degrees or decreased below 60 degrees. Although 80 degrees was most effective in changing the green color of the fruit to yellow, pears ripened at this temperature were so tough and woody that they were practically inedible. Fruit held at 50 degrees often failed to ripen properly, frequently breaking down before becoming sufficiently soft. The relationship of temperature to the quality attained by Kieffer pears was similar in both fresh and canned fruit. Prolonged cooking not only failed to materially soften fruit which had failed to soften properly at

ripening-room temperatures which were too high, but also imparted an undesirable pink discoloration to the fruit.

While Kieffer pears ripened at 60 degrees F generally were not equal in quality to Bartlett pears they were not greatly inferior.

Another advantage in ripening Kieffer pears at 60 degrees F is that this temperature is much less conducive to development of decay than 70 or 80 degrees. This is illustrated in Table I.

TABLE I—Influence of Ripening Temperature on Decay Development in Kieffer Pears (Lockport, N. Y.) After 17 Days in Ripening Room

Temperature (Degrees F)	Firmness (Pounds Pressure)	Percent Decay (Mostly Rhizopus)
80	9.70	10.3
70	6.82	6.6
60	3.20	1.3

Chemical analyses of the 1932 fruit showed that the quality of the fruit as influenced by temperatures could not be associated with any of the following constituents: solids soluble in alcohol, solids insoluble in alcohol, total sugar, titratable acidity or total astringency (1). There was, however, a positive correlation between conversion of protopectin to soluble pectin and the rate of softening, this conversion of course being greater at 60 degrees F than at higher or lower temperatures. Practically all of the sugar in these pears was reducing sugar.

Relationship of temperature to composition of internal gases:—Studies were made on the internal gases of Kieffer pears as it was thought that the retardation in the rate of softening of the fruit at temperatures of 70 degrees F or above might be the result of particularly high content of CO_2 within the tissues of the fruit ripened at these temperatures.

The fruit used in this phase of the work was picked at Arlington Farm, Va., on September 21. The internal gases were extracted by a modification of the method suggested by Magness (2). The modification consisted primarily in the use of a much larger extraction cylinder (500 cc) which permitted the analysis of about 250 cc of fruit tissue. The period of extraction was standardized at 5 minutes. The gas thus extracted was analyzed in an Orsat gas analysis apparatus, in which the standard 100 cc gas burette was replaced with a 25 cc burette instead of the Bonnier-Mangin apparatus. This method of extracting and analyzing gas was found not only to be more rapid than the method suggested by Magness but also gave more reliable results in this work.

The results of the analyses of internal gases as given in Fig. 5 and Table II indicate that the accumulation of a somewhat higher CO_2 content within the fruit ripened at temperatures of 70 degrees F or above is only a minor factor in the retardation of the rate of softening at these temperatures. The analyses of internal gases shown in

Fig. 5 and given in Table II are the averages of three determinations made at approximately 6-day intervals. Fig. 5 shows that although the percentage of CO_2 increases and the percentage of O_2 decreases as the temperature is raised to 80 degrees F there is no sharp change in the CO_2 content from 60 to 70 degrees, as would be expected if accumulation of CO_2 were the only factor in causing a decreased rate of softening at the higher temperature. It can be seen in Table II that the fruit held at 60 degrees in an external atmosphere of 5.3 per cent CO_2 softened more than similar fruit held in ordinary air at 80 or 90 degrees despite the fact that the former fruit had a much higher percentage of CO_2 and a lower percentage of O_2 within its tissues. The high accumulation of CO_2 in this case did, however, have some effect in slowing the rate of softening, as can be seen when the firmness of this fruit is compared to that ripened at 60 degrees in ordinary atmosphere.

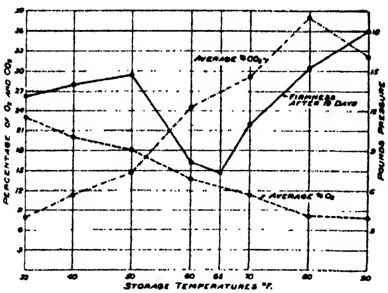

FIG. 5. Interrelationship of ripening temperature, change of firmness, and composition of internal gases.

TABLE II—INTERRELATIONSHIP OF TEMPERATURE AND EXTERNAL ATMOSPHERE TO COMPOSITION OF INTERNAL GASES AND DEGREE OF SOFTENING OF KIEFFER PEARS (ARLINGTON FARM, PICKED SEPT. 21, 1933)

Temperature (Degrees F)	External Atmosphere	Average Composition of Internal Gases		Firmness After 19 Days
		CO_2 (Per cent)	O_2 (Per cent)	
		Firmness at time of harvesting 14.4±.21		
90..........	Ordinary	32.1	8.0	18.0 ±.63
80..........	Ordinary	38.0	8.2	14.97±.92
60..........	Ordinary	25.0	13.6	8.04±.37
60..........	5.3 Per cent CO_2 15.1 Per cent O_2	51.7	5.8	11.34±.30

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Some Observations on the Behavior of Cured Ripe Mission Olives, Preserved at Low Temperatures

By H. C. Diehl and J. A. Berry, *U. S. Department of Agriculture, Seattle, Wash.*

THE preservation of unsterilized cured ripe olives by freezing has been studied recently with the objective of retaining much of the original flavor and quality of the olives, as is often accomplished for many fruits and vegetables preserved by this method (1, 2).

Observations were made during 1933 on the behavior of cured ripe olives, packed both with weak salt brine and without liquid in both air-tight and non-air-tight containers, and held at air temperatures of—5, 15, 20, 25, and 32 degrees F for 10 months. Suggestions for the commercial freezing preservation of ripe olives are given elsewhere (2); the present paper records briefly some observations on the reaction of ripe olives to low temperatures and ice formation.

Cured ripe Mission olives, before freezing, had a firm, resilient texture with an apparently homogeneous tissue, faintly showing radial striations from seed to skin. The skin was smooth and glossy, giving the appearance of plumpness to the fruit. The seeds adhered somewhat to the flesh, and could not be separated readily, when the olives were cut in half.

The most noticeable effect of ice formation in olive tissues was their softer, more tender nature when thawed, and this softening varied with the low temperature used for freezing the fruit. This effect apparently was due to two causes, at least, namely, (a) The formation of lenticular ice masses at crystallization foci, particularly at points in the tissue where such foci appeared initially or where weakness in structural cohesiveness existed, and (b) the relief from strains set up in the olive tissues due to localized water withdrawal to the crystallization foci.

In either case, pockets or cavities were observed in the tissues when thawing took place, and an irregularly spongy structure remained, the relative resiliency of which was influenced by the number, size, and positions of these cavities. These factors, in turn, seemed to be determined by low temperature effects, within the range studied, that is, the degree of undercooling as well as the rapidity and type of ice formation. Duhamel du Monceau (3), Caspary (4), Sorauer (5), and others have referred to the formation of ice pockets and cavities in plant tissues; hence the phenomenon is not a new one, although perhaps not previously observed in connection with freezing preservation of horticultural products.

The ice formation, preceding the appearance of these cavities, was not intercellular, in the strict sense of the word but took place between grosser structural elements in the tissues, which to the naked eye appear as parallel striations, extending outward from the seed. The long axis of these cracks was then usually perpendicular to the seed. Microscopic examination of the frozen and thawed tissues, confirmed the gross observations.

The characteristic appearances of ripe olives in cross section after holding at —5, 15, 20 and 25 degrees F are shown in Fig. 1.

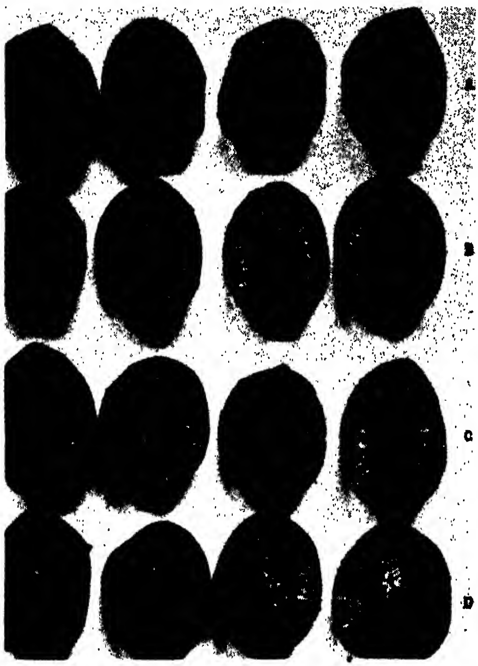

FIG. 1. Samples of halved ripe Mission olives. showing the characteristic cavities in thawed olives, after ice formation had occurred. All lots held 7 months at air temperatures as follows: A,—5 degrees; B, 15 degrees; C, 20 degrees; D, 25 degrees F.

The olives, frozen at —5 degrees F, upon thawing showed relatively small cavities, frequent in number, and mostly confined to the flesh nearest the seed, with some appearing close to the skin, but few or none in the remaining cortex. The texture of these olives was uniformly tender, and not really spongy, while the seed separated freely from the flesh, in contrast to its usual behavior in the unfrozen olives, or in those held at other low temperatures.

After storage at 15 degrees F, ripe olives showed cavities, resembling those found in fruit held in —5 degrees, but the size of the pockets appeared generally to be slightly larger, their number was reduced, and they were less concentrated near the seed although they were largely absent in the mid-cortical portion of the tissues.

In ripe olives held at 20 degrees F, however, the cavities were comparatively large, numerous and dispersed through all parts of the olive flesh. These olives had a decidedly inferior texture, were very spongy, the flesh separated raggedly from the seed, and there was considerable loss of oily juice upon cutting.

Ripe olives, held at 25 degrees F almost invariably showed no cavities or tissue splitting, and none were observed in fruit stored at 32 degrees. The flesh appeared to be cohesive, homogeneous and with either a tough or a cheesy consistency, which tended to become more pronounced with longer storage, particularly in the olives held at 32 degrees. There was other evidence indicating that ice formation never occurred in the olives stored at 32 degres, and only rarely took place in olives held at 25 degrees. Since ripe olives cannot be stored for long at these last two temperatures without microbial spoilage, the ultimate texture changes in them has no practical significance.

These differences in the fruit probably resulted partly from the fact that, where the environmental temperature is relatively low, as for instance —5 degrees F, undercooling is often terminated by the sudden appearance of a large number of crystallization foci, which quickly achieve maximum size with water drawn from the immediate vicinity. On the other hand, where the environmental temperature is higher, as at 20 degrees, ice formation may begin early at a few crystallization centers, and subsequent increments build up the size of these ice masses by water movement extending over relatively considerable tissue distances. Where structural strain adjustments in tissues are involved, the general reasoning given above also holds true.

During freezing temperature storage of ripe olives, a characteristic skin wrinkling was observed, which seemed to be influenced by the type of ice formation in the flesh as well as by the presence or absence of a liquid medium about the fruit. This appeared to be similar to the phenomenon referred to by Hilts and Hollingshead (6) as shrivelling due to frost. Examples of this skin wrinkling are given in Fig. 2, B and C, which were frozen "dry" at 15 and 20 degrees F, respectively.

The ripe olives frozen "dry" at —5 degrees F (Fig. 2, A) exhibited little or no skin wrinkling. The extensive and deep wrinkling, with evidences of external mold growth, in olives held in non-air-tight containers at 25 and 32 degrees F (Fig. 2, D and E) was not due to ice formation effects, but was caused by desiccation from the fruit stored for long periods at those temperatures.

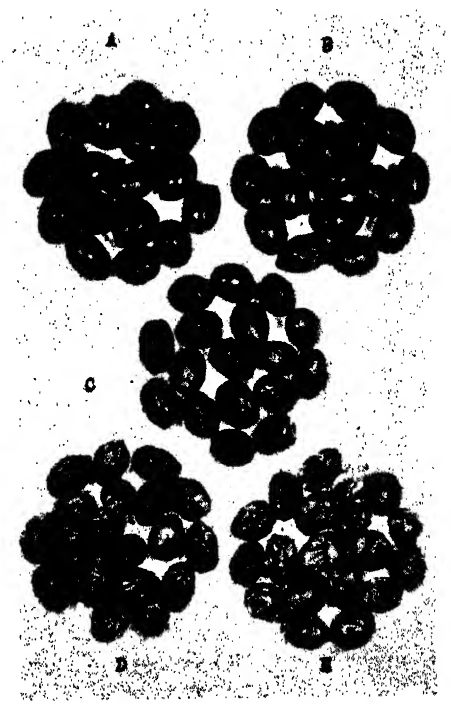

FIG. 2. Samples of ripe Mission olives packed without liquid in non-air-tight containers and held for 7 months at the following air temperatures: A,—5 degrees; B, 15 degrees; C, 20 degrees; D, 25 degrees; and E, 32 degrees F; showing skin wrinkling related to ice formation, shrivelling due to desiccation and color bleaching due to activity of anaerobic or facultative bacteria.

Olives held in brine at all of these temperatures did not exhibit surface wrinkling caused by ice formation or shrivelling due to desic-

cation, regardless of the type of container used. Similar effects of a liquid environment on plant tissues during exposure to freezing temperatures have been observed before.

When ripe olives were held in air-tight containers at 25 and 32 degrees F, a bleaching of the normal color took place after a few months storage. This color alteration, similar to that previously described by Cruess and Guthier (7) in studies of bacterial activity on olives at ordinary air temperatures, was a change from the usual dark brown or black hues to tawny brown or orange-brown hues. The characteristically bluish tips of moist cured ripe olives had a violet color in the bleached fruit. Color changes were not observed in olives held in non-air-tight containers at 25 and 32 degrees, or in those actually frozen at the lower temperatures, regardless of relative tightness of container to atmospheric oxygen.

The tawny or orange-brown hues disappeared quite rapidly when the olives were restored to normal atmospheric conditions at room temperatures during thawing, and the dark brown or black color reappeared, with perhaps slight diminution in intensity and uniformity. The appearance of the olive flesh was not materially affected during this exterior change in color.

Obviously, a reversible oxidation—reduction phenomenon is present in such cases and the chromogen in the olive skin is deprived of oxygen by the activity of anacrobic or facultative bacteria, growing in the oxygen deficient atmosphere of the hermetically sealed containers. Since the enzymes of the olive tissues are killed during the pickling process, they are not involved in these color changes.

In fact, it was possible to influence the color of normally cured ripe olives in the same manner, by placing samples in large test tubes with enough weak brine to cover, antl permitting them to stand for a few days at room temperature. In such cases, the vigorous growth of bacteria, probably in part anaerobic, as noted by Cruess and Guthier, resulted in definite bleaching.

As noted, olives stored in the temperature range, 25 to 32 degrees F, underwent slow microbial spoilage, irrespective of type of pack. For example, using nutrient agar the bacterial count for the brine on olives in air-tight containers stored at 32 degrees F rose from about 100,000 per cc to upwards of 50,000,000 per cc in 6 months, while mold growth, as Cladosporium had occurred also in non-air-tight containers. The bacteria growing in the olives held at 25 and 32 degrees were mainly of the Flavobacterium, Achromobacter, and Pseudomonas genera—all soil or water organisms.

From the bacteriological viewpoint, 20 degrees F must be regarded as the highest possible temperature for the freezing preservation of olives, and even here slow mold growth in non-air-tight containers is possible. It has been found that olives from —5 and 15 degrees storage show spoilage in 5 to 7 days at room temperature.

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The Carbohydrates of Dried California French Prunes (Prune D'Agen)

By E. Mrak, C. Smith, and V. Henriques, *University of California, Berkeley, Calif.*

THE literature concerning the carbohydrates of California dried French prunes is meager and the data are incomplete. Atwater and Bryant (1) reported 73.3 per cent total carbohydrates including fiber. Jaffa (6) determined the total sugar in various size grades of prunes. Gale and Cruess (5) gave percentages of total solids, sucrose, and invert sugar of prunes from Santa Clara, Sacramento and San Joaquin districts. Nichols and Reed (12) have compared the sugar contents of prunes from Santa Clara, Napa-Sonoma, San Joaquin and Sacramento districts. Ramsay (14) reported 1.44 per cent woody fiber in dried prunes. McCance and Lawrence (9) analyzed cooked dried prunes for total reducing sugars, pentose sugars as arabinose, and non-fermentable substances. Olig, Brust and Stumpf (13) studied the chemistry of fresh prunes in respect to their use in jam manufacture in Germany. Mrak and Cruess (11) reported the pectin, invert sugar, and sucrose content of prune pulp.

The present investigation was undertaken in order to obtain more complete knowledge of the carbohydrates of dried California French prunes; and to determine the nature of some of the substances composing the 20 to 30 per cent of prune flesh unaccounted for in the analyses reported by others. Furthermore, prunes from various California districts have been shown to vary in sugar and specific gravity (12). Therefore, samples from four districts were analyzed in order to obtain some idea of the magnitude of variations in carbohydrate components, though the number of samples used was not sufficient to obtain the complete range of variations.

Determinations were made of reducing sugars, sucrose, dextrose, levulose, reducing substances after fermentation, soluble solids, dextrin, starch, alcohol precipitable substances, pectin, pentosans, crude fiber, cellulose, lignin and mannites.

Materials and Methods

Large samples of dried prunes from Sacramento, Napa, Santa Clara and San Joaquin districts of California were pitted, passed through a coarse grinder once and then a nut butter grinder twice.

Reducing sugars were determined by the Shaffer and Hartman method (15) after clarifying with saturated neutral lead acetate and deleading with sodium oxalate. Dextrose was determined by the method of Lathrop and Holms (8) and levulose by difference. Sucrose was inverted by cold inversion with HCl. Total reducing sugars were determined before and after inversion. Reducing substances after fermentation were determined and reported as reducing sugars. Dextrin, starch and hemicelluloses were determined by the

methods described by Leach (7). The A. O. A. C. methods (2) were used for obtaining the water and alcohol extracts, alcohol precipitate, pectin, pentosans, and crude fiber. Cellulose was determined in accordance with the procedure given by Dore (4) and lignin by the procedure described by Morrow (10), Jan Smits (16) method was used for the mannite determinations. The data are reported on a 20 per cent moisture basis.

Results and Discussion

The percentages of reducing sugars found agree well with the findings of other investigators (5, 6, 12). The ratio of dextrose to levulose was more than two to one in the prunes from the warmer Sacramento and San Joaquin districts, whereas it was less than two to one in the prunes from the cooler Santa Clara and Napa districts. This gives rise to the question whether the D/L ratio is naturally higher in prunes from the warmer districts, or whether some of the levulose is lost during drying of the fresh fruit in the sun because of higher drying temperatures. Cruess and Christie (3) observed a rapid loss of sugar when raisins were dehydrated at 185 degrees F. After becoming nearly dry but at lower temperatures, the effects were negligible unless the raisins were allowed to become very much over-dried. The data from the present study of prunes, however, do not warrant such a statement and conclusions cannot be made until experimental data regarding the relation of drying temperature to the D/L ratio of prunes are obtained. A second point of interest concerning the D/L ratio is the crystallizing of dextrose on the surface of some prunes and not on others. It seems possible that if the D/L ratio were very high dextrose might crystallize earlier during storage.

The quantities of sucrose found were similar to those reported by Gale and Cruess (5).

The data for starch, dextrin, and hemicelluloses are given in Table I. Dextrins were negligible, but in four of the samples starch was present in larger quantities than was expected in view of the common belief that the prune is a non-starch fruit. As in the case of the sugars, there was considerable variation ranging from a negligible quantity to almost 2 per cent. Hemicelluloses were present in considerable quantities and they account for a large part of the previously undetermined fraction. Leach (7) states that hemicelluloses may be reported as arabinose. However, since the type or types of pentose sugars present were not determined qualitatively, the data were reported as reducing sugars. The values found for the reducing materials after fermentation and the pentosans indicate the importance of pentose sugars in the constitution of prunes.

In Table II data on other cell wall carbohydrate constituents are given. These indicate the presence of considerable quantities of pectin, lignin and cellulose. These substances may be included in the unreported fraction. The determination for pentosans, hemicelluloses, and pectin, however, probably overlap each other to some extent.

Although considerable quantities of cell wall constituents were

TABLE I—CARBOHYDRATES IN ALCOHOL EXTRACT AND ALCOHOL EXTRACTED FLESH (ALL DATA ON 20 PER CENT MOISTURE BASIS)

Locality	Reducing Sugars (Per cent)	Dextrose (Per cent)	Levulose (Per cent)	D/L Ratio	Red Sugars After Inversion With HCl (Per cent)	Sucrose as Reducing Sugars (Per cent)	Starch (Per cent)	Hemi-Celluloses as Red Sugar (Per cent)	Dextrins (Per cent)
Santa Clara A....	51.5	33.98	17.17	1.98	52.09	.59	1.54	12.96	Negligible*
Small Santa Clara	47.50	31.03	16.48	1.88	50.71	3.21	1.17	18.09	Negligible*
Napa............	47.86	31.21	16.74	1.86	49.31	1.45	Negligible*	14.78	Negligible*
Small Sacramento	34.65	24.56	10.10	2.43	40.12	5.47	Negligible*	18.45	.47
Sacramento large	46.12	30.24	15.88	2.04	46.87	.75	1.86	8.67	Negligible*
San Joaquin......	38.42	26.93	11.49	2.34	40.26	1.84	1.17	14.43	Negligible*

*Less than .1 per cent.

TABLE II—ANALYSES OF PRUNES (ALL RESULTS ON 20 PER CENT MOISTURE BASIS)

Locality	Water Soluble Solids (Per cent)	Reducing Sugars After Fermentation (Per cent)	Reducing Sugars After Fermentation and Inversion with HCl (Per cent)	Alcohol Precipitable Material (Per cent)	Pectin as Pectic Acid (Per cent)	Pentosans (Per cent)	Crude Fiber (Per cent)	Lignin (Per cent)	Cellulose (Per cent)	Invert After Boiling Flesh in 1 Per cent HCl (Per cent)
Santa Clara A	54.81	1.84	2.38	2.59	1.23	2.68	1.86	5.07	4.36	50.06
Santa Clara small......	57.48	1.59	2.08	2.85	1.30	3.06	*	5.08	3.48	49.42
Napa........	62.24	1.23	2.33	2.53	1.42	2.67	1.56	5.24	3.42	51.51
Sacramento small......	61.40	1.17	2.55	2.41	1.20	2.59	1.75	4.46	3.32	40.51
Sacramento large.......	56.19	1.24	2.14	2.05	1.13	2.64	*	6.06	4.86	50.18
San Joaquin..	62.59	1.39	2.04	2.33	1.23	2.51	2.00	4.54	4.11	40.01

*Determinations not made.

found to be present, most of them were destroyed by treatment with boiling acids or bases as indicated by the columns for crude fiber in Table II. Boiling prune flesh with 10 per cent HCl caused destruction of some of the carbohydrate materials and decreased the copper reducing values, whereas boiling prune flesh in a 1 per cent HCl solution increased the copper reducing power.

Mannite has not been reported in the tables because of failure to obtain a clear supernatent liquid as required by the method used. This may have been caused by the absence of mannite or by the presence of substances contained in the fermented water extract of prunes used for the determinations.

Summary

1. The flesh of dried prunes from Santa Clara, Napa, Sacramento, and San Joaquin districts of California were analyzed for a number of carbohydrates heretofore unreported for dried prunes.

2. The dextrose to levulose ratio was found to be less than two in prunes from the cooler Santa Clara and Napa districts and greater than two in prunes from the warmer Sacramento and San Joaquin districts.

3. Sucrose, starch, and hemicelluloses varied considerably with different samples. Hemicelluloses or pentose sugars and pentosans apparently form a large part of the unreported fraction of prunes. Dextrins were present in negligible quantities.

4. Other constituents found present in considerable quantities were pectin, lignin and cellulose. Apparently much of these materials were destroyed in the determination of crude fiber as indicated by the relatively small per cent of other substances present.

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The Effect of Methods of Packing on the Condition of Apples Packed in Barrels

By Paul L. Harding, Dean H. Rose and J. M. Lutz, *U. S. Department of Agriculture, Washington, D. C.*

BARRELED apples from the United States often reach European markets in unsatisfactory condition. Slackness of pack is probably the most serious defect. Reports of 4 to 6 inches of slackness are not infrequent (Figs. 1 and 2) and barrels arriving at European markets only a little over half-full have on rare occasions been observed. According to the Bureau of Agricultural Economics of the United States Department of Agriculture, 19 per cent of the United States barreled apples sold at the Liverpool auction in 1932–1933 were slack. In the previous season 25 per cent of the barrels were graded and sold at Liverpool as slacks. The loss at Liverpool (to American shippers) for barreled apples arriving slack was estimated at $109,000 for 1931–1932. This represents but one European market and similar conditions prevailed in others.

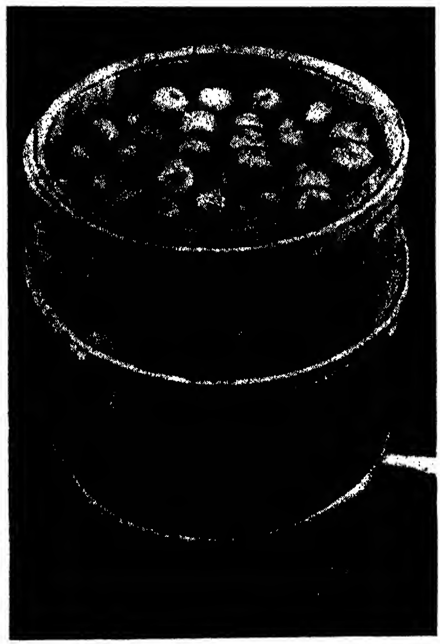

Fig. 1. Slack barrel discharged at Liverpool. Barrels landing in this condition are usually discounted $1.44 to $1.95. (Picture furnished by the Bureau of Agricultural Economics, U. S. D. A.)

Since most of the fruit arriving at Liverpool, Southampton, etc., is reshipped to various parts of the United Kingdom without refrigeration, it must arrive at the port in good condition and also withstand reshipment.

Methods

During the 1931 shipping season an overseas transportation test was made to ascertain the influence of methods of packing barreled apples, particularly the amount of racking and the height of pack, on the condition of the fruit on arrival in England.

The investigations were continued in 1932 and were outlined specially to determine the effect of various amounts of "shaking" and "racking" on the condition of the fruit.

The fruit used in 1932 was all of the Rome Beauty variety, grown and packed at Hancock, Maryland. An attempt was made to duplicate export shipments of fruit, the packed barrels being shipped by rail to Arlington Farm, Virginia, and placed October 25 under storage conditions, similar to refrigerated and ordinary stowage aboard ship. At the end of 1 month of storage, all the fruit was inspected and notes were taken on the amount of decay, bruising, visible skin breaks and slackness of pack.

FIG. 2. A barrel of Winesap apples shipped to England under ordinary stowage. This barrel is representative of the entire shipment. (Picture furnished by the Bureau of Agricultural Economics, U. S. D. A.)

"Shaking" means the settling of the fruit in the barrels by giving the barrel three or four quick sharp jolts. The amount of shaking varied from the check treatment which received none, to certain lots which received as many as five shakings at intervals during the filling of the barrels. In the latter treatment, the barrel was shaken when $^1/_6$ full, $^1/_3$ full, $^1/_2$ full, $^2/_3$ full, and $^5/_6$ full.

"Racking" means a vigorous tipping back and forth of the barrel when it was nearly full, with the "plug" or "follower" in place. During such racking the barrel was inclined enough from vertical so that the chime on one side was raised 3 or 4 inches off the floor. The number of times the barrel was racked refers to the number of complete backward and forward motions. Thus, if a barrel was racked 15 times, it was jolted 30 times.

Standard barrels of 3-bushel capacity were used and for all the treatments (1932) were filled with apples to a height of ¾ inch above the staves. In 1932 four series of barrels were prepared, as follows:

Series A:—Barrels shaken and racked; 20 barrels of apples size 2¼ to 2½ inches, 20 barrels size 2½ to 3 inches. Two barrels of each size were subjected to each treatment; treatments varied from no shaking to shaking five times during the filling process. All were racked 15 times. Series B:—Barrels shaken but not racked; 20 barrels of apples size 2¼ to 2½ inches. Series C:—Barrels headed with a screw press; 8 barrels with combination treatment of shaking and racking. Series D:—Barrels shaken on a wooden floor; 8 barrels with combination treatment of shaking and racking.

The barrels of series A, B and D were headed with a machine press. Those of series A, B, and C were racked on a concrete floor. Series D was racked on a wooden floor.

Duplicate lots of each treatment were stored for 1 month in ordinary storage, in which the fruit temperatures ranged from 52 to 68 degrees

F with an average of 60 degrees, and in a cold storage room maintained at about the temperature conditions usually found in refrigerated chambers for apples aboard ship. Fruit temperatures in the cold storage room varied but slightly from 36 degrees.

The method adopted for the classification of bruised and "broken skin" apples was similar to that used in the 1931 export test. Apples were considered badly bruised if they had one or more flattened surfaces 1 inch or more in diameter, or four or five somewhat smaller. Apples with two to four small bruised spots were classed as slightly bruised (Figs. 3 and 4). "Broken skin" refers to apples with visible skin breaks; these in turn were further classified as to the severity of the bruise.

FIG. 3. Cross section view of a badly bruised Rome apple, illustrating the affected tissue.

All barrels were opened at the "tail" end and each quarter-barrel of apples was inspected and classified separately. Most of the bad bruising was found in the top quarter (tail end) of the barrel.

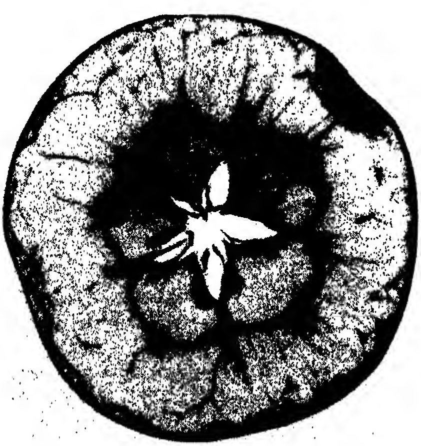

FIG. 4. Cross section view of a slightly bruised Rome apple.

SUMMARY OF RESULTS AND CONCLUSIONS

Although these investigations are still in progress, the following tentative conclusions have been reached as a result of the work carried on in 1931 and in 1932.

1. Insufficient filling or racking was responsible for an inch or less of slackness of experimental shipments in which decay and breakdown were not important factors. Barrels of York Imperial apples which were filled only to the tops of the staves of the barrel and had been slightly racked arrived at London showing only an inch of slackness in the

barrel. The same degree of slackness was found in barrels which were well shaken and racked but filled only to the top of the croze (the groove below the tops of the staves).

2. The height of pack and amount of racking may have a very pronounced indirect effect on the degree of slackness by influencing the amount of bruising and skin breaks. The latter are especially serious since they open the way for the entrance of pathogenic organisms which cause decay and thus slackness. Shaking the barrels two or three times while they are being filled, racking 15 times when the barrels are nearly full with the "plug" or "follower" in place and then filling to about ¾ inch above the tops of the staves seems sufficient to prevent appreciable settling of the apples in transit. Racking with the plug or follower in place is very effective in settling the apples in the barrel and thus preventing slackness due to subsequent settling, although some shaking also is necessary. If heavier shaking or racking is practiced it is well to decrease the height of the pack to prevent excessive bruising and skin breaks. Filling more than ¾ inch above the tops of the staves causes an undue amount of bruising and skin breaks, especially when normal shaking and racking have been given. Over-filling does not replace adequate shaking and racking in the prevention of slackness.

3. Refrigeration during the ocean transit period is effective in the prevention of slackness in varieties such as Jonathan or Grimes Golden as these are especially subject to decay and breakdown and are generally shipped when the outside air temperature is high. Refrigeration is generally not necessary for varieties such as York Imperial which are shipped during a colder season of the year.

4. Barrels headed with a machine press which applies the pressure directly downwards contained somewhat fewer fruits with broken skins and bad bruises than did similar barrels headed with a hand-operated screw press.

5. Barrels racked on a concrete base were somewhat more tightly packed than those racked on a wooden floor. The effects on bruising and decay were similar.

6. The average number of apples (size 2¼ to 2½) increased progressively from 718 in barrels not shaken to 761 in barrels shaken five times, when the amount of racking was constant. Barrels racked 15 times contained an average of 738 apples per barrel, while those not racked contained 722, when the amount of shaking was the same.

7. Slightly less bruising occurred in barrels which were "ring-tailed" than in those which were "jumble-filled."

Primordial Development of the Inflorescence of the Concord Grape

By J. C. Snyder, *Iowa State College, Ames, Ia.*

IN a recent investigation dealing mainly with the initiation of the inflorescence of the Concord grape, the author (5) found that the initiation of the cluster primordia occurs soon after the eyes are formed on the growing shoot. (The term cluster instead of bunch is used.) The present article describes that part of the development of the inflorescence occuring before the androecium and gynoecium undergo specialization.

Drawings representing the average number of clusters (three) produced on each of 125 shoots for the year 1931–32 are shown in Fig. 2. A number of clusters sufficient to show the progressive changes occurring during the period from flower bud initiation to preblossoming are drawn and tabulated in chronological order. Clusters taken at 11 periods from June 5 to May 8 of the following year, are included. From these drawings the stage of development of the clusters at any date during this period June 5 to the following May 8) can be determined. For example, a solitary cluster in the form of a simple protuberance is evident on June 5 and three clusters are discernible by June 27. Complete details regarding the materials and methods are given in a previous paper (5).

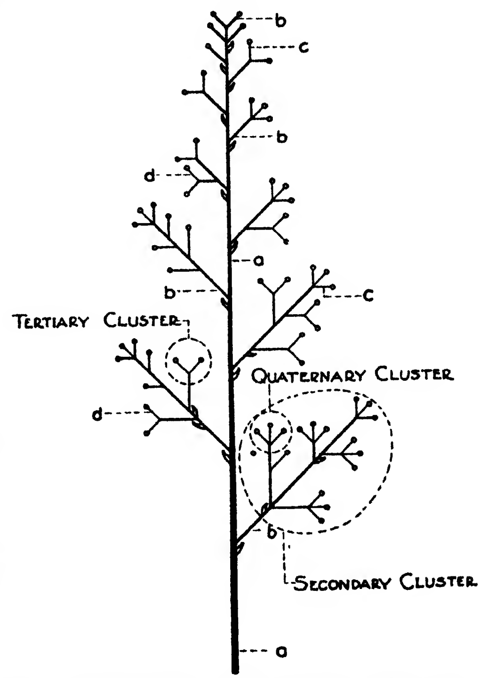

Fig. 1. Diagramatic cluster showing subdivisions.

In the absence of a system of structural nomenclature suitable for describing the cluster, or bunch as it is probably more frequently called, the author introduces the one given below. The main axis of an inflorescence of the racemose panicle type, of which the grape is an example, is called the rachis (Fig. 1 a). Branches arising directly from the rachis are called axes of the first order and subsequent branches in turn are called axes of the second and third orders (Fig. 1, b and c). The entire inflorescence, including the various axes and the fruit borne by them, is referred to as the primary or main

cluster. Axes of the first order, including the fruit they bear, are called secondary clusters (Fig. 1). Progressive subdivisions of the secondary clusters are called tertiary and quaternary clusters (Fig. 1).

In the initial stage the cluster primordium consists of a simple oval protuberance identical in shape to a leaf primordium. The initiation of the first main cluster is discernible on June 5, as indicated in Fig. 2. The lobe arising apparently from epidermal and hypodermal cells on the dorsal side of the slightly elongated primordial cluster is the first evidence of a cluster bract. This bract, rounded at first, soon becomes very pointed and adheres to the adjacent part of the slightly elongated axis of the main cluster. Presently secondary clusters appear as irregular swellings near the base of the cluster. These swellings, also arising from epidermal and hypodermal cells, elongate and form prominent lobes which, instead of becoming pointed as is the case with bract lobes, become distinctly oval. The formation of secondary clusters in this way continues so that by June 27 several can be seen in cluster 1 (Fig. 2). Bracts subtending the secondary clusters are evident. The formation of qauternary and occasionally quintic clusters follows in rapid succession in the basal section of the main cluster. In the course of the branching just described the cluster takes on the shape of a mature cluster so that at this time, nearly 12 months before the cluster is ripe, it is a miniature form of a mature cluster.

The development of the main clusters with reference to the location of the eyes on the fruiting shoot can best be described by dividing the shoot into three sections. The section with the two basal eyes is referred to as the basal section and that with the two apical eyes is referred to as the apical section except when the shoot contains 14 or more eyes, in which case the apical section includes three to five eyes. The remaining eyes constitute the middle section. At the time of the first collection, June 5, each shoot bore a total of six eyes, making two in each of the three sections (Fig. 2). The second eye on the shoot, located in the basal section, is the first to initiate a cluster. The eyes in this section being laid down several days prior to those in the middle section, may be expected to precede the latter in cluster initiation. The basal eyes, instead of remaining more advanced than those in the middle section, lag behind so that by June 13, when the shoots are 18 inches long these basal eyes bear a single cluster, while those in the middle section bear two clusters. At this time cluster 1 of the eyes in the middle section is subtended by a bract, while cluster 2, like the solitary cluster in the basal and apical sections is still a simple protuberance. Consequently, about 1 week after the first primordial main cluster on a shoot is evident the third and fourth eyes show greater development than either those in the basal or apical sections.

The number of eyes, increasing simultaneously with the elongation of the shoot, reaches eight by June 20, when the shoot is 2½ feet long and cluster 1 in the middle section bears a secondary cluster. In the basal section at this time a solitary cluster subtended by a bract represents greater development than the simple protuberant main

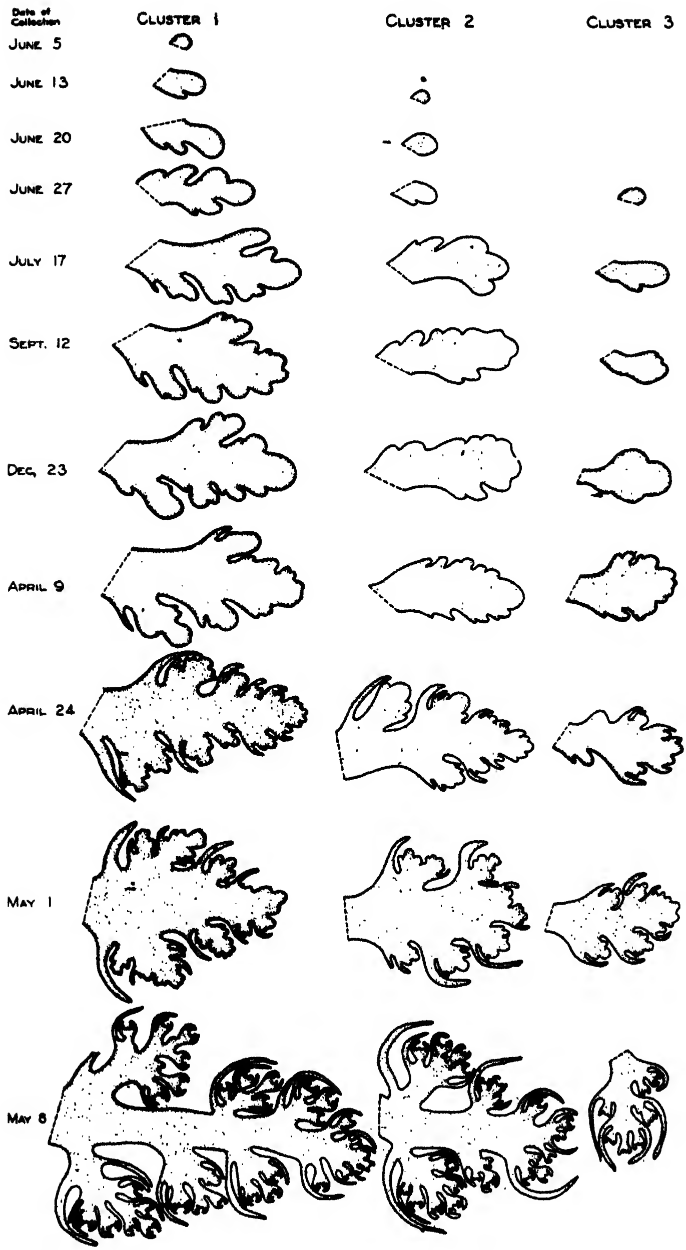

Fig. 2. Drawings showing the development of the clusters from differentiation of cluster primordium to pre-blossoming.

cluster in the apical section. Again, as was true in the preceding collection, maximum development occurs in the middle section.

Outstanding development is made in the middle section during the next week, ending June 27, when each shoot bears ten eyes. The most advanced eyes in the middle section contain three main clusters, namely, cluster 1, showing numerous secondary clusters, some of which are subtended by bracts; cluster 2, subtended by a bract; and the rudimentary third cluster. These clusters represent greater development than has been observed heretofore. In contrast to this striking development in the middle section each eye in the basal section still shows a single cluster with no further development. In the apical section, however, there is evidence of two clusters: cluster 1 subtended by a bract and cluster 2 in the form of a simple protuberance. Thus the buds in the apical and basal sections, in approximately the same stage, show the usual laggard development in comparison to the middle section.

On July 17, nearly all eyes in the middle section contain three primordial clusters, namely, cluster 1, containing numerous secondary clusters, some of which are subtended by bracts; cluster 2, showing several rudimentary clusters; and cluster 3, merely subtended by a bract. These clusters indicate progressive development in this section. In the basal section cluster 1 is nearly as advanced as cluster 1 in the middle section, but clusters 2 and 3 when present show no evidence of secondary clusters. In the apical section the ultimate eye possesses a single cluster while the penultimate eye shows no evidence of division. The tendency for all clusters on the shoot to reach the same stage of development is first apparent at this time. The above statements indicate that all the eyes on the shoot except those in the apical section are considerably more advanced on July 17 than on June 27.

The shoots, with their tips still in a growing condition on Sept. 12, bear approximately 35 eyes. In the middle section not only are secondary clusters in cluster 1 more numerous than they were on July 17 but many of them bear tertiary clusters. Cluster 2 of this section, somewhat smaller than cluster 1, shows numerous secondary clusters, some being subtended by bracts. Cluster 3 with several secondary clusters, none of which are subtended by bracts, is in a more primitive stage than is cluster 2. The eyes in the basal section are nearly as advanced as those in the middle section. In the apical section, however, they are much more primitive, resembling corresponding eyes of the previous collection. This rudimentary condition obtains in the apical section as long as the shoot is in a growing condition. Thus the tendency for all eyes to reach the same stage of development continues during the late summer when numerous eyes are being laid down.

Examination of the eyes made during October and November, before winter killing had occurred, indicates that the eyes near the tip are nearly as advanced as those in the middle section. Further development of the eyes, including the flattening of the floral axis

and the initiation and development of the various floral structures, does not appear to be associated with their location on the shoot.

The facts set forth above indicate therefore that (a) the initiation of cluster primordia occurs in basifugal order throughout the length of the shoot, (b) clusters appear in the basal section of the shoot first but are soon surpassed in development by those in the middle section, and (c) all buds on the cane pass the winter in the same stage.

The initiation of cluster 1 occurs almost a week before there is any discernible trace of cluster 2. A bract subtending cluster 1 appears simultaneously with the initiation of cluster 2. Apparently the initiation of cluster 3, instead of following immediately, occurs about 2 weeks after the initiation of cluster 2 (Fig. 2). During this time cluster 1 produces a bract and several secondary clusters while cluster 2 produces a bract. It should be noted here that a period of approximately 3 weeks (June 5 to 27) is required for the initiation of the three clusters. Examination of Fig. 2 shows what rapid development each of the three clusters undergoes during early July. Cluster 1, for example, practically doubles the number of secondary clusters and cluster 3 not only enlarges considerably but also produces a cluster bract.

Altho the development of the clusters is less rapid during the 2 months ending Sept. 12, each cluster makes progressive development during this period (Fig. 2). Cluster 1, for example, produces tertiary clusters and cluster 3 produces secondary clusters. A minor development seen in cluster 2 is the presence of bracts subtending secondary clusters. Even though the development made during the fall period is very slight there is a discernible increase in the size of tertiary clusters in many basal secondary clusters of cluster 1 as well as an increase in the number of secondary clusters in clusters 2 and 3. This retardation of development continues until early April when all three clusters assume a second period of very rapid development (Fig. 2).

A noticeable enlargement of many tertiary clusters in cluster 1 is the first indication of the rapid spring development. These enlarged tertiary clusters are about to produce quaternary clusters and may be said to be in the prequaternary stage. This enlargement of tertiary clusters in cluster 1 is paralleled by a similar enlargement of secondary clusters in clusters 2 and 3. The latter also produce prominent bracts at this time. Soon after the clusters reach this condition, congruent with the swelling of the buds there is a marked acceleration of development. *Flattened floral axes in cluster 1 at this time mark the first evidence of flower bud formation.* Simultaneously with flower initiation in cluster 1, many tertiary clusters in cluster 2 attain the prequaternary stage and cluster 3 shows evidence of secondary clusters. While all three clusters are making the above development, bracts subtending subclusters in each of the main clusters elongate and become pointed, almost overlapping the subclusters in some cases.

The initiation of definite floral structures immediately follows the

flattening of the floral axis. The calyx, evident in cluster 1 on May 1 when the eyes begin to break, is the first floral structure to appear. Presently the calyx forms a cap enclosing the developing flower and the clusters are discernible with the naked eye. Before the calyx cap is completely formed, however, the petals appear, followed immediately by the initiation of the stamens. The development of the calyx, petals, and stamens occurs in basifugal order on the shoot.

Once the cluster primordium is present, each of the three clusters develops according to the same plan. Cluster 1, initiated nearly 1 week before cluster 2, undergoes rapid development immediately. Cluster 2 appears to develop at about the same rate after it is differentiated, but due to the fact that the development of both clusters 1 and 2 is arrested simultaneously in the fall, cluster 1 is larger than cluster 3. Obviously this variation in the size of the three clusters is apparent as soon as all three clusters are discernible and it persists in parallel proportions throughout the development of the cluster primordia.

In describing the primordial development of the inflorescence as it occurred during the year 1931–32, at Ames, Ia., the author is aware that the time at which it occurs may vary in other regions and during other seasons.

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The Treatment of Frosted Grape Vines

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PEROLD (1) voices the opinion of most viticulturists when he states that, "the treatment of frosted grape vines depends on the stage of development of the vine." In the case of shoots that are less than 2 inches long "the shoots killed by the frost are broken off." When the shoots are 6 to 12 inches long and only the tips but not the flower clusters are killed, "we merely cut off the dead tips of the shoots. If the inflorescences have also been killed, we cut back all such shoots with a sharp knife to about 1/5-inch from the old wood." Other viticulturists make the general statement that it does not pay to do anything.

Observations have indicated that both of the above views are defective since they do not take into account the fruiting habits of different varieties or the facility with which the grape shoot produces laterals when the tip of the green shoot is destroyed.

Frosts in the latter part of April in 1932 in Merced County and in 1933 in San Joaquin County, produced conditions which were ideal for the testing of the above recommendations as well as other treatments of frosted grape vines. At the time of the frost the shoots were 6 to 14 inches in length in the different vineyards. The degree of injury varied from the mere killing of the tips in some vineyards to the complete destruction of all the shoots in others.

Presentation of Data—Fruiting Responses

The degree of injury of the vines used, the treatments employed, and the crop obtained are shown in Table I.

The data of the table show that where the shoots of Thompson Seedless were killed to below the flower clusters no increase in crop was obtained by any of the treatments. Similar fruiting responses were obtained when the shoots were entirely killed. The second series of treatments show that when any flower clusters remain uninjured it is a mistake to remove the shoots on which they are borne. Such removals reduced the crop in every instance.

The cutting off of the frosted tips of the shoots when merely the tips were killed had no influence on the crop. This discredits the belief that a toxin produced in the frosted part of the shoot moves down to injure the unfrosted part.

In the Malaga the rubbing off of the frosted shoot when all of the shoots were killed to the base had no influence on crop. From ¼ to 1/3 of a crop was produced on both the check and the treated vines. However, where the shoots were killed to below the flower clusters but not to the base, the vines from which the shoots were removed produced 1/3 of a crop, while the check vines produced practically no crop. Also the small amount of fruit that was produced by the

TABLE I—THE DEGREE OF FROST INJURY, THE TYPE OF TREATMENT, AND THE NUMBER AND WEIGHT OF CLUSTERS AND THE CROP PRODUCED

Variety	Degree of Killing of Shoots	Treatment	Number Clusters to a Vine	Weight of Cluster (Pounds)	Crop to a Vine (Pounds)
Thompson Seedless (Sultana outside of the United States)	To below the clusters, base not killed	Check	11.0	0.18	2.0
		All shoots removed	6.1	0.34	2.1
		Canes cut back to 4 or 5 buds, all shoots removed.	6.5	0.32	2.1
		Same as above, but shoots not removed	9.5	0.21	2.0
Thompson Seedless	65 to 75 per cent of shoots killed to below clusters	Check	18.0	0.76	13.7*
		Canes cut back to 4 or 5 buds	6.8	0.41	2.8
Thompson Seedless	Only tips killed, a few clusters injured	Check	27.0	—	1 tray of raisins
		Frosted tips cut off	26.0	—	1 tray of raisins
Malaga	Killed to base	Check	3.1	1.6	5.0
		All shoots removed	3.8	1.5	5.7
Malaga	To below the clusters, base not killed	Check	10.0	0.2	2.0
		All shoots removed	6.1	1.4	8.6*
Tokay	Killed to base	Check'	38.0	1.03	39.1†
		All shoots removed	37.0	1.06	39.2†
Tokay	70 to 90 per cent of shoots killed to below clusters, base not killed	Check	25.8	0.88	22.7
		All shoots with injured clusters removed	36.4	1.05	38.3‡
Tokay	20 to 30 per cent of shoots killed to below clusters	Check	18.0	0.78	14.1
		All shoots with injured clusters removed	15.4	0.94	14.5†
		All shoots removed	9.7	1.05	10.2

*One-third of a full crop.
‡Three-fourths of a full crop.
†Approximately a full crop.
The variation in the age of the vines in the different vineyards has made it desirable to give these notes on crop.

check vines was mostly second crop and was worthless for table fruit. The difference in fruiting in this case was owing entirely to the difference in the number of lateral growing points of the dormant buds of the spurs that were forced into growth. Where the shoots were removed the lateral growing points of the dormant buds were forced to develop, while on the check vines the profuse growth of

lateral shoots from the axillary buds of the unfrosted parts of the green shoots practically prevented the development of lateral growing points of the dormant buds.

With Tokay, again, the rubbing off of the frosted shoots when they were all killed to the base had no influence on crop. Almost a full crop of fruit was produced by both the check and the treated vines. In this variety the lateral growing points in the dormant buds are quite fruitful, hence the forcing of these growing points into growth by the complete frosting of the shoots resulted in the production of a good crop. Where a majority of the Tokay shoots were killed to below the flower clusters but not to the base the removal of the shoots resulted in a 50 to 70 per cent increase in crop. Not only did these vines produce more crop than the check vines but the clusters were larger and more uniform in size. A portion of the crop of the check vines was second crop; that is, small clusters borne on lateral shoots produced by the axillary buds of the unfrosted basal part of the green shoots. The slightly smaller percentage of a full crop obtained on the treated vines of this series as compared to the other two on this variety was apparently owing to the poor fruiting wood in one of the vineyards. In this vineyard the spurs were weak and it is not at all unlikely that a considerable percentage of the lateral growing points of the dormant buds were sterile.

Where only 20 to 30 per cent of the Tokay shoots were killed to below the flower clusters, the removal of the shoots so injured had a correspondingly small influence on crop. Although the clusters were somewhat more uniform in size, this improvement, alone, was not sufficient to offset the cost of removing the shoots. In this variety the removal of shoots with uninjured clusters, again, resulted in a reduction of total crop. The difference in the number of good clusters was relatively small, yet, it serves to emphasize the undesirability of removing any uninjured clusters in the treatment of frosted vines.

The Fruiting Wood for the Next Season

The fruiting wood of the check and treated vines was equally good for all of the varieties used when the shoots were entirely killed. When the basal portion of the shoots were not frosted, the wood for the next year was much improved by the treatments which reduced the number of shoots that developed after the frost to about the same number as were growing before. In the spur or short pruned varieties this was accomplished by the removal of the shoots that were killed to below the flower clusters, while with the cane or long pruned varieties the fruit canes were cut back to four or five buds.

The cutting of the fruit cane of Thompson Seedless back to four or five buds in 1932 improved the wood sufficiently to reduce the pruning time 1 to 1½ hours per acre below that for the check vines. A reoccurrence of frost in 1933 made it impossible to check on the influence of the better wood on the yield of that year. The pruning time for the Malaga vines on which the injured shoots were removed was reduced to $^2/_3$ of that of the check vines. The crop of the

treated vines that escaped frost in 1933 was practically normal, while on the check vines where many lateral shoots were produced by the unfrosted basal part of the green shoots the wood was so poor that these vines produced only $^2/_3$ of a crop. The wood growth on the other short pruned varieties was similar to that indicated for Malaga.

Conclusions and Recommendations

The above results indicate that the treatment of frosted vines should be governed by the fruiting habit of the variety concerned and by the degree of injury of the shoots.

Fruiting habit:—The fruiting habit, that is, the extent to which the three growing points of the dormant buds are fruitful, determines the crop that can be produced by vines on which the flower clusters have been destroyed by frost. In Thompson Seedless where only the primary growing point of the dormant bud is usually fruitful, little or no crop was produced following the frosts that killed the shoots to below the flower clusters. In fact, the only first crop clusters that could be produced by this variety after a killing frost are those which are borne on shoots arising from buds which were dormant at the time of the frost. The treatment of frosted vines of this variety will not usually result in any increase in yield over the untreated vines. The same would be true of other varieties having similar fruiting habits, namely, Sultana and possibly Emperor.

In the Malaga where frequently one lateral growing point of the dormant bud is fruitful in addition to the primary growing point a small amount of fruit was produced by the treated vines after the frost. Unless the shoots were killed entirely their removal on this variety, when the flower clusters were destroyed by frost, should result in the production of ¼ to ½ of a crop. Other varieties of about the same fruiting habit, such as, Gros Colman, Molinera, Olivette Blanche, etc., should respond similarly.

With a further increase in the number of fruitful growing points in the dormant bud, as in the Tokay where two or more are fruitful, the vines are capable of producing almost a full crop of fruit after a killing frost. This variety produced almost a full crop when the shoots were entirely killed or when the unfrosted basal parts of the green shoots were removed so as to force the lateral growing points into growth. A similar response was obtained with Muscat, Alicante Bouschet, Carignane, and Zinfandel. The Ribier and most of the short spur pruned wine grape varieties which are similar to these varieties in fruiting habit should respond similarly.

Degree of injury:—Where only the tips of the shoots are frosted the best recommendation is to do nothing. When the shoots are killed to just below the flower cluster, remove the injured shoots on varieties similar to Malaga and Tokay in fruiting habit, but do nothing on varieties similar to Thompson Seedless in fruiting habit except where one wishes to improve the fruiting wood. For the latter cut the fruit canes back to four or five buds. Again, when the shoots are entirely killed, do nothing.

Acknowledgments

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The Effect of Sulphur Dioxide Fumigation on the Respiration of Emperor Grapes

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SULPHUR dioxide has been an effective fumigant in the shipping and storage of California grapes, retarding mold growth when present in the grapes in only small quantities and causing no visible or serious injury to the fruit when certain concentrations are not exceeded. These concentrations have been discussed in a previous paper (2). Winkler and Jacob (3) found that sulphur dioxide in the relatively high concentrations of 75 to 300 mg per kilo slowed down the respiration of Grenache grapes at temperatures of 65 to 75 degrees F. In view of these results, the effect of smaller quantities of sulphur dioxide on the respiration of grapes at transit and storage temperatures was thought to be of interest in the study of factors involved in commercial grape fumigation.

METHODS

Emperor grapes of the usual shipping maturity were selected for the experimental work. The fumigation of this variety with sulphur dioxide has been of particular importance since it is often held in cold storage until January or February. Samples of the fruit were fumigated and the respiration rates determined at temperatures of 32, 36, 43, and 53 degrees F, the latter two representing the equivalent of average bottom and top layer temperatures, respectively, in refrigerator cars. The respiration rates of untreated fruit from the same lots were determined simultaneously at the above temperatures. Sulphur dioxide analyses of the grapes immediately after removal from the fumigation chamber were made and expressed as p. p. m. The respiration rate was determined by absorption of the CO_2 evolved by passing the air stream from the respiration chamber through KoH in Truog absorption towers, titrating the carbonate formed with HCl, using the double titration method. Flow-meters were used to measure and keep constant the volume of air pulled through the respiration outfits. Two kilos of grapes were used in each respiration chamber and the runs were made for periods of 90 to 287 hours, depending on the temperature. The results obtained during the seasons of 1931 and 1932 are given in Table I.

RESULTS

From Table I, it is evident that the respiration of Emperor grapes was reduced at transit and cold storage temperatures by sulphur dioxide fumigation. As little as 12 p. p. m. of SO_2 in the tissues reduced the respiration rates to from 74 to 82 per cent of those of untreated fruit, and 22 p. p. m. in the grape tissue had similar effects.

These concentrations of sulphur dioxide were not accompanied by injury to the fruit and are about the concentrations used commercially for this variety. Commercial injury occurred as bleaching of the color of the grapes in the lots containing 43 and 87 p. p. m. of SO_2. In the lot containing 87 p. p. m., respiration was reduced to 8 per cent of normal at 32 degrees and 18 per cent at 36 degrees F. The respiration rates given in Table I represent the average rates for periods of 4 to 13 days immediately following fumigation. Subsequent determinations to find if the retardation of metabolic activities is permanent would be of interest.

TABLE I—THE RESPIRATION OF EMPEROR GRAPES AS AFFECTED BY SULPHUR DIOXIDE AND TEMPERATURE

Temperature (Degrees F)	Hours Run	Respiration Rate (Mg of CO_2 per Kg HR)			Fumigated Grapes	
		Untreated (a)	Fumigated (b)	$\frac{b}{a}$	SO_2 Analysis (P.p.m.)	Condition
Sugar in Juice, Balling Scale 21.1, Season 1931						
53	90	11.90	9.37	.79	12	No injury
43	90	6.63	4.88	.74	12	No injury
36	178	4.51	3.72	.82	12	No injury
32	178	2.61	2.15	.82	12	No injury
Sugar in Juice, Balling Scale 22.6, Season 1932						
53	124	7.53	6.09	.81	22	No injury
43	124	4.57	3.58	.78	22	No injury
36	287	2.04	1.91	.94	22	No injury
32	287	1.74	1.43	.82	22	No injury
Sugar in Juice, Balling Scale 19.2, Season 1931						
43	144	5.34	2.89	.54	43	Some bleaching
53	150	10.73	6.99	.65	87	Badly bleached
43	150	4.40	1.87	.43	87	Badly bleached
36	241	3.34	.59	.18	87	Badly bleached
32	241	2.24	.18	.08	87	Badly bleached

Overholser and Cruess (1) in studying the darkening of apple tissue found that treating apple juice with sulphur dioxide destroyed the organic peroxide and incidentally the oxidizing system, thereby preventing browning. Sulphur dioxide apparently did not affect the peroxidase or the oxidizable tannoid substance in apples. No attempt has been made to determine the effect of sulphur dioxide on the oxidizing system of grapes, but from the above work a reasonable explanation for the retardation of respiration would be in its destruction of the organic peroxide involved in the respiration process. However, in the case of injured grapes, much more than this has no doubt taken place, for many cells are plasmolyzed and killed.

The chief value of sulphur dioxide fumigation is its effect on mold growth, but the slowing down of the metabolic activities of the fruit

is of small but definite value in reducing loss of stored carbohydrates and reducing the refrigeration required to compensate for the heat of respiration.

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The Comparative Gross Morphology of the Raspberry[1]

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THIS is a discussion of the gross morphology of the below-ground parts of the red and black raspberry. The term "adventive" as applied to roots and shoots is used in the general sense of Priestly and Swingle (1).

The red raspberry is commonly propagated by means of canes bearing at their basal ends a piece of the parent root, usually with some lateral roots. In spite of its anatomy, this root is still occasionally referred to as a "horizontal underground stem" or stolon with the inference, expressed or implied, that the vertical cane is merely one of its lateral branches.

When the red raspberry plant is set, roots already present may resume growth whether they are located on the base of the cane or on the parent root. In addition, more adventive roots may appear. Shoots bearing leaves which, if below ground, are scale-like and rudimentary, may develop either from axillary buds on the parent cane or from adventive buds which develop on the roots. The latter explains the spreading propensities of the red raspberry. Adventive roots may appear on the shoot internodes at any point below ground; in this manner may arise layers of roots at levels successively higher, as continued cultivation toward the row adds successive layers of earth.

The succulent adventive shoots of root origin, which often produce roots and should include a piece of the parent root, are used for summer propagation of the red raspberry.

The black raspberry is propagated commercially by means of tips consisting of a layered portion of the parent cane bearing a strong terminal bud above a radiating mass of adventive roots, which usually arise at the base of the petiole at each node where roots occur. Some of the lateral buds on the parent cane may also be rooted at their bases, especially when the terminal bud has been injured or when the parent cane is unusually vigorous. Laterals from the main canes may also tip layer just as the terminal itself.

When the tip is set, root growth is continued chiefly from roots already present, while the terminal bud resumes the elongation of the main axis. Some of the lateral buds below ground may also resume growth when the terminal is injured or when the tip plant is vigorous.

In established black raspberry plants, shoots come from axillary buds, particularly those below ground at the base of the old canes, but not from the roots as in the case of the red raspberry. This localization of shoot origin limits the black raspberry to a relatively

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slow crown expansion compared with the more rapid spread of the red raspberry.

The young canes of the black raspberry may occasionally root feebly at their bases, but they do not form extensive root systems as does the parent crown.

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Fruit Bud Formation in Brambles

By George F. Waldo, *U. S. Department of Agriculture, Corvallis, Ore.*

MANY of the problems that confront investigators working with small fruits have a bearing more or less directly on the time of fruit bud differentiation and the rate and kind of development of the fruit bud. Several workers have contributed much to our knowledge of these processes in the strawberry, but only a few have contributed such information in the other small fruits.

The work reported here was done on brambles grown at Glenn Dale, Maryland, near Washington, D. C., in 1929 and 1930. and at the Oregon Experiment Station, Corvallis, in 1932 and 1933. In order to examine a large number of buds, free hand sections were made and examined immediately under the microscope. In most cases mounts were made of representative sections.

The process of fruit bud formation was essentially the same in all the various types of bramble fruits. The fruit is borne on laterals which appear during the spring from buds on canes which grew the previous year. The differentiation process is as follows: The vegetative bud shows first, a broadening of the growing point, and second, an elongation of this growing point with axillary growing points appearing on each side. The terminal and axillary growing points later develop flower parts, the terminal normally becoming the terminal flower of the cluster. The axillary growing points may become the terminal flowers of lateral flower clusters. At the base of the first differentiated fruiting lateral, secondary buds sometimes differentiate flower buds and develop into one or two other fruiting laterals.

In the red raspberries, the fall fruiting varieties such as Ranere and Lloyd George form fruit buds as soon as shoot elongation ceases in the summer. The Lloyd George in Oregon ceased growing about July 15 in 1933, and fruit bud formation developed rapidly, starting first in buds at the terminals and progressively in buds downward from the terminals. The downward development of flowering ceased gradually during September. Where Lloyd George was growing vigorously, more bloom and fruit was produced and rapid development of fruit buds proceeded farther down the canes than where growth was less vigorous.

In Maryland, buds of Ranere below the fall fruiting region showed no evidence of fruit bud differentiation until after November 15 and little development was noted between December 15 and March 8. Analogous buds of Lloyd George, however, showed the primary growing point well elongated by Oct. 20. By November 21 axillary growing points were found, but from this date there was little further development until February 24.

In Oregon, fruit bud differentiation was found to proceed generally from the terminals of the canes downward in all red raspberries.

Table I shows that on the same date buds in different locations on the cane are in different stages of development. The camera lucida drawings in Fig. 1 show the fruit buds from three different locations on a Cuthbert cane in different degrees of development. Definite blossom differentiation was found in buds from the basal region (0–18 inches) of Lloyd George canes on Oct. 5, 1932, and on Sept. 25, 1933. On the same dates axillary growing points were appearing in buds above 40 inches from the base. Similar conditions were found in buds of all the red raspberry varieties examined in Oregon, as shown in Table I.

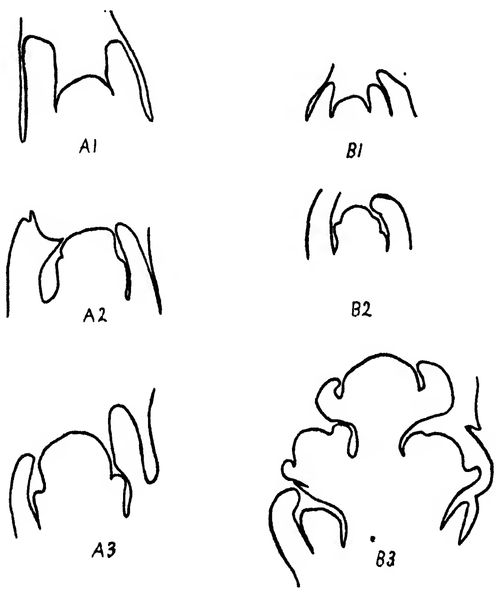

FIG. 1. (A) Fruit buds of Evergreen blackberry; (1) Oct. 14; (2) Nov. 7; (3) Feb. 8.
(B) Fruit buds from different portions of a single cane of Cuthbert red raspberry on Sept. 28, 1933; (1) 10 to 30 inches from base; (2) 50 to 70 inches from base; (3) tip region.

In order to compare time of differentiation among the different varieties, buds were examined from the portion of the cane producing the most fruit. This portion in all varieties except Cuthbert was determined to be from 30 to 50 inches from the base. In Maryland, Lloyd George and White Queen with visible differentiation in October and well developed flower parts on November 22, were the first to form fruit buds in this portion of the cane. Van Fleet came next with differentiation in late October. Most varieties, however, including Ranere, Sunbeam, Chief, Latham, Viking, and *Rubus innominatus,* did not show definite differentiation until late November or December. In these later developing varieties there was little further development beyond definite differentiation during the winter.

The Lloyd George and Ranere in Oregon were found to have differentiated fruit buds 40 to 50 inches from the base of the canes as early as Aug. 30. The Cuthbert was found differentiating fruit buds in the terminal portions of the canes and as far down the cane as 50 inches from the base. At Puyallup, Wash., definite fruit bud differentiation was found in buds 40 to 50 inches from the base of the canes on Nov. 18, 1932, and axillary growing points were already beginning elongation in buds at 60 to 70 inches. Cuthberts from Multnomah County, Oregon, showed definite differentiation in the

TABLE I—TIME AND DEGREE OF FRUIT BUD DEVELOPMENT IN DIFFERENT LOCATIONS ON CANE OF RED RASPBERRY VARIETIES IN OREGON IN 1932 AND 1933. UNLESS OTHERWISE INDICATED, LOCATIONS WERE MEASURED FROM BASE OF CANES

Variety	Definite Fruit Bud Differentiation	Axillary Growing Points Appearing	Axillary Growing Points Elongating	Pistil Primordia Appearing on Primary Flower
Ranere	Aug. 30, 1933 27–40 in.	Oct. 6, 1932 20–30 in.		Oct. 18, 1933 50–60 in. Terminal
Lloyd George	Oct. 5, 1932 0–18 in. Aug. 30, 1933 40–50 in. Sept. 25, 1933 10–25 in.	Oct. 5, 1932 30–54 in. Sept. 25, 1933 40–50 in. Nov. 7, 1933 10–30 in.	Oct. 5, 1932 54–64 in. Aug. 30, 1933 50–60 in.	
Cuthbert (Puyallup, Wash.) (Multnomah County, Ore.)	 Nov. 19, 1932 40–50 in. Dec. 27, 1932 0–20 in.		 Nov. 19, 1932 60–70 in. Dec. 27, 1932 40–60 in.	 Nov. 19, 1932 70–80 in.
Cuthbert (Corvallis, Ore.)	Sept. 28, 1933 50–70 in. Nov. 9, 1933 10–30 in.	 Nov. 9, 1933 60–80 in.	Sept. 28, 1933 Terminal	Sept. 1, 1932 Terminal
Newburgh	Nov. 10, 1932 20–30 in. Sept. 27, 1933 40–50 in.	Nov. 10, 1933 40–50 in. Sept. 27, 1933 Terminal		
Latham	Feb. 8, 1933 30–40 in. Sept. 25, 1933 Terminal Nov. 9, 1933 50–60 in.			
Chief	Nov. 9, 1932 20–30 in. Feb. 8, 1933 10–20 in.	Nov. 9, 1933 50–60 in.	Nov. 9, 1932 35–40 in. Feb. 8, 1933 30–40 in.	
Viking		Oct. 16, 1933 70–80 in.		
Marlboro	Oct. 17, 1933 20–40 in.			
Antwerp	Oct. 17, 1933 20–40 in.		Oct. 17, 1933 Terminal	

basal buds (0–20 inches) on Dec. 27, 1932. Newburgh, Viking, Marlboro, and Antwerp were found with differentiated fruit buds 30 to 50 inches from the base in late September and October, while Chief and Latham showed differentiation in the same part of the cane in early November.

Studies were made in Maryland of black and purple raspberry varieties and other species which root at the tips of the canes. Only the buds on the laterals within 20 inches of the main cane were examined. Cumberland and Black Giant black raspberries, Potomac, and U. S. D. A. No. 231 purple raspberries, and *Rubus coreanus* showed fruit bud differentiation in October. In Oregon, Plum Farmer black raspberry, and Potomac and U. S. D. A. No. 231 purple raspberries showed fruit bud formation taking place in early November. Selections of Asiatic Rubi, *R. coreanus, R. biflorus,* and *R. lasiostylus,* showed indications of differentiation on Sept. 16, 1932, and axillary growing points appeared by Dec. 5, 1932. It was not possible to determine whether there is a definite trend in fruit bud differentiation up or down the canes in this class of brambles, as in the red raspberries, although in the native black raspberry, *R. leucodermis,* the buds near the base were much less developed than those toward the ends of the canes. In this species there were indications of fruit bud differentiation 20 to 40 inches from the base on Oct. 8, 1932 and axillary growing points were appearing in buds on the same canes 100 to 120 inches from the base.

In Maryland the upright blackberries, including the species *Rubus canadensis* and the varieties Joy and Eldorado, had well differentiated fruit buds on their laterals with many axillary growing points beginning to elongate by November 1. Ward, Mersereau, McDonald and Jumbo had buds in similar condition in January. In Oregon the Robinson, Alfred, Early Harvest, and Russell showed indications of fruit bud differentiation on Aug. 11, 1933. The Eldorado, Lawton, Alfred, and Early Harvest varieties showed indications of differentiation on August 26. All these varieties had well differentiated fruit buds with axillary growing points appearing by Oct. 2, 1933. There was little difference in the degree of development in the fruit buds on laterals, but the basal buds on the main cane rarely showed any fruit bud formation in October. Stuart, on Oct. 11, 1932, showed no differentiation in buds below 40 inches from the base, while axillary growing points were found elongating in buds above 80 inches from the base.

The Himalaya blackberry did not show any fruit bud differentiation until January in Maryland. In Oregon no differentiation was observed until Feb. 17, 1933. The Brainerd, a cross between an eastern upright blackberry and the Himalaya, showed definite differentiation in Maryland in November. In Oregon differentiation had occurred and axillary growing points were appearing on Nov. 23, 1933.

The Oregon Evergreen showed definite differentiation in early December in Maryland and during November in Oregon. The Young dewberry differentiated fruit buds in October both in Maryland and Oregon. The Loganberry showed fruit bud formation in Oregon

during September and early October. The Ideal Wild, Santiam, Mammoth, wild trailing blackberry (*Rubus macropetalus*), Lucretia, and Austin Thornless, all showed definite fruit buds in Oregon in October. In these berries there was but little evidence of any trend in fruit bud differentiation either up or down the cane, although in the wild trailing blackberry and Loganberry there were found some differences in the development of the buds in the different portions.

Studies on the further development of the fruit buds after differentiation show that in Maryland there is little development of fruit buds between December 1 and March 1. The upright blackberries which differentiated early and developed rapidly showed little change after Nov. 1. Although a severe freeze in December, 1932, interfered with further studies in Oregon in the early part of 1933, it was quite evident that the buds of Loganberry, Young dewberry and Oregon Evergreen continue to develop during the winter under western Oregon conditions (Fig. 1-A). The freeze killed many of the main buds in the Oregon Evergreen and Loganberry, but where the canes were not also killed, the small lateral buds, which were vegetative at the time of the differentiation of the main bud, later formed fruit buds.

In the Oregon Evergreen there are secondary buds, the largest of which is outside and slightly below the main or central bud. This bud differentiates flower parts a little later than the main bud. In the other bramble fruits studied there are similar buds, usually very small and vegetative, but sometimes showing flower parts and developing into smaller and weaker flower clusters than the primary buds. Studies on these buds are in progress. It was quite evident that the fruit produced the year after the December freeze came largely from such buds after the rudimentary flower parts had been killed in the main bud.

Observations in these investigations are in agreement with those of MacDaniels (1) in that all buds in brambles are potentially fruit buds. There is a definite tendency for fruit bud formation in red raspberries to begin in the buds at the terminal end of a cane at about the time growth ceases and to begin in lower buds at successively later dates. There is in general but little fruit bud devlopment between late December and March. More development occurs under the mild winters in Oregon than in Maryland. Time of differentiation and degree of development in a given period probably differ in various parts of the country. Fruit bud differentiation in the lateral or secondary buds, when it does occur, follows that of the primary bud. Injuries to the primary buds seem to stimulate fruit bud differentiation in these secondary buds.

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A Preliminary Study of the Fruiting Habit of the Black Raspberry—Rubus Occidentalis

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Abstract

The complete paper is to be published as a bulletin of the Colorado Experiment Station.

THIS is the second of a series[1] intended to evolve a pruning practice from knowledge of the plant's natural fruiting habit under Colorado conditions.

Fifteen Plum Farmer plants 2 years set were selected from a row of 60 hills which had been treated similarly the year before fruiting, except in the manner of summer pruning and thinning. Primocanes of a like number of Honeysweet and Cumberland hills were prepared alternates.

Primocanes in 40 hills were shortened to 24 inches as soon as they had attained 30 inches in length. Twenty of these hills were also thinned to the 7 best canes in each hill. The remaining 20 of the original 60 hills were allowed to grow untreated. In each of these three treatments five hills were selected each year for yield records. Randomization within the row was accomplished by selecting hills of similar vigor, which were necessarily scattered by chance. Canes were tagged and measured in spring before shoot elongation was appreciable. Separate records from each 6-inch section of every main cane and its branches show the place of origin, the magnitude, and date of the yield. Counts of buds and laterals show the proportion of productive wood in various parts of the hill.

The results show that though pinching (shortening of primocanes) makes a decided difference in the distribution of fruit over the plant, there is no significant yield difference between treatments. The varieties studied give a favorable response to summer pruning (pinching), and thinning of canes is undoubtedly worth while, though the optimum amount of thinning is not determined by this investigation.

Median sections of buds taken at weekly intervals from June 10 to October 26, 1931, and from April 25 to June 10, 1932, were prepared as permanent mounts by standard histological methods and studied for manner and date of fruit-bud differentiation. From September 12, through December, 1932, camera lucida sketches of fresh, freehand sections of buds at base, middle and near tip of branches were made weekly for comparison with permanent mounts.

Flower primordia were not distinguishable until new leaves had formed in spring, although there is indication that differentiation may begin before it can be detected by microscopic inspection.

[1]"Raspberry Investigations," the first of which was "Preliminary Study of the Fruiting Habit of the Red Raspberry—Rubus strigosus," by R. V. Lott, Colorado Agr. Exp. Sta. Bul. 367. 1931.

Raspberry and Blackberry Cane Measurements

By Geo. M. Darrow, and Geo. F. Waldo, *U. S. Department of Agriculture, Washington, D. C.*

In 1931, Lott (2) published records of cane measurements of irrigated raspberries at the experiment station at Fort Collins, Colorado, where the plants were not allowed to suffer from deficient moisture supply or from winter injury. There the growth habit of the Cuthbert was not considered as desirable as that of the Latham because its buds were farther apart on the lower part of the cane than those of the Latham. Cane diameter was found to be closely correlated with yield. Lott's records indicated growth conditions different from those in the Pacific Northwest where there is high humidity in spring and early summer, moderate temperatures, and long days during the growing season, especially during that part of the season when growth is made on current food manufacture rather than on stored food.

In 1931 the results of a survey (3) of the production practices on 69 red raspberry farms near Tacoma, Washington, were published, giving the yields in pounds per acre from fields from 2 to 35 years old. The average yield for ten fields with the highest records was 10,386 pounds (about 7,000 quarts) per acre and for the ten lowest, 2,983 pounds (about 2,000 quarts) per acre. These data suggested the possibility of obtaining cane measurements from these and other fields which could be used as standards of comparison for varietal, environmental, and cultural studies. The yields obtained from the most productive of these fields are among the best ever reported in this country. Cane measurements were made in two of these fields of Cuthbert red raspberries.

In 1930, Field No. 1 which consisted of 3½ acres, yielded an average of 11,870 pounds (about 8,000 quarts) per acre and field No. 2 about 4,500 pounds (3,000 quarts) per acre. Cane measurements taken the following spring (1931) are shown in Table I.

TABLE I—Average Cane Measurements in Two Fields Near Tacoma, Washington, 1931

	Canes per Plant				Buds per Cane		Diameter (Inches)		
	Height	Left	Good	Poor	Entire Cane	5.5 Feet	Base	5.5 Feet	Ratio
Field No. 1	10.4′	7.0	7.0	0	52.4	17.3	0.47	0.45	0.96
Field No. 2	8.7′	4.5	2.7	1.7	45.5	19.4	0.398	0.20	.72

Buds per Foot, Bottom to Top

	1	2	3	4	6	6	7	8	9	10
Field No. 1	2.7	3.7	3.2	3.1	3.0	3.2	5.7	6.9	9.0	10.9
Field No. 2	4.3	4.0	3.2	3.0	3.5	5.3	6.5	8.3	10.5	—

Since raspberry canes in the Puget Sound, Washington, region are commonly pruned back to about 5.5 feet, the crop is produced on the basal 5.5 feet. The records in Table I indicate that the higher-producing fields have taller canes, fewer buds per cane on the part left, a greater base diameter, and less taper in the first 5.5 feet than the lower-producing fields. Most of the buds on vigorous canes of all red raspberry varieties are on the terminal 3 feet, the part removed in pruning in the Northwest. The work of the Western Washington Experiment Station (1) agrees with the experience of the grower of Field No. 1, that better crops (nearly as many berries of larger size) are harvested from 5.5 feet of cane having 17.3 buds than from 10.4 feet of cane having 52.4 buds. Canes in Field No. 1 with an average of 3.1 buds per foot for 5.5 feet bore more than canes in Field No. 2 with 3.5 buds per foot. Each plant in Field No. 1 bore about 5 pounds of berries or about 0.7 pound per cane. Length of cane and ratio of base diameter to diameter at 5.5 feet are simply measures of vigor, and vigor is directly related to yield. Number of buds per foot is another measure of the vigor of the plant; the more vigorous the growth the fewer the buds per foot.

A year later the canes of Field No. 1 were measured again, also canes in specially good 1-, 2-, and 3-year-old Cuthberts in other fields as shown in Table II.

TABLE II—Cuthbert Raspberry Cane Measurements in 1-, 2-, 3-Year-Old and Mature Fields in Oregon and Washington, 1932

	Canes per Plant	Height	Branches	Length of Cane per Plant (Inches)	Diam. of Cane (Inches)			
					Base	5	5.5	Ratio
One-year...	—	5.2′	4.2	30.6	0.87	—	—	—
Two - year.	4.7	—	2.2	—	0.61	0.33	—	0.54
Three-year.	4.4	—	0	—	0.46	—	0.40	0.87
Field No. 1.	6.3	—	0	—	0.49	—	0.43	0.87

In these fields in the Northwest, age made a difference in the character of growth. Good growth the first year is characterized by canes of nearly 0.9 inch in diameter at the base with several branches per cane. The second year more but smaller canes (about 0.6 inch diameter) with fewer branches, and the third year and thereafter still more and taller canes with a still smaller diameter (about 0.45 inch) and without branches are characteristic. The fewer branches and taller canes in 2-year and older fields may be attributed to effects similar to those of tree crowding in forests. Very large numbers of suckers and shoots in and near the crowns may appear in mature fields, as many as 75 to a plant having been counted. Crowding and shading kill out some, but thinning with the hoe is commonly practiced to remove most of them before the picking season.

In 1933, records of the number of buds, fruiting laterals, and berries on 25 canes of each of six varieties at Corvallis, Ore., were obtained. These records were grouped on the basis of the size of the

canes to show the relation of size of cane and number of buds and fruiting laterals to yield, as shown in Table III.

TABLE III—AVERAGE DIAMETER AT BASE AND NUMBER OF BUDS, FRUITING LATERALS AND BERRIES ON THE BASAL 4 FEET OF LARGE AND SMALL CANES OF SIX VARIETIES OF RED RASPBERRIES AT CORVALLIS, OREGON, 1933

Variety	Base Diameter (Inches)	Number of Buds	Number of Fruiting Laterals	Number of Berries
Lloyd George	0.50	32.0	31.1	312.5
	0.39	34.0	26.1	199.0
Newburgh	0.43	24.4	16.4	129.8
	0.35	27.1	18.8	125.4
Ulster	0.46	21.3	16.0	135.5
	0.36	25.1	16.7	114.4
N. Y. 2563	0.48	20.8	17.0	141.2
	0.37	24.6	19.2	94.7
N. Y. 2584	0.47	19.3	18.8	225.8
	0.38	19.7	21.5	227.8
N. Y. 2585	0.48	16.0	14.0	287.0
	0.34	21.5	15.6	209.0

In all six varieties there were more buds and fruiting laterals on the basal 4 feet of the weaker (smaller and shorter) than of the more vigorous canes. In only one variety (N. Y. 2584) was there more fruit on this part of the smaller canes, and that not enough more to be significant. On the other hand, four varieties produced many more berries on large canes with fewer buds and fruiting laterals than on the small canes. The N. Y. 2585 had the fewest fruiting laterals and the most berries to each while the Lloyd George had the largest number of fruiting laterals and the most berries per 4 feet of cane. The number of buds which develop and the number of berries per fruiting lateral very largely determine production. The percentage of buds which develop was about the same for strong as for the weak canes, but the number of berries per fruiting lateral was much greater for the strong canes.

At the experiment station at Corvallis, Oregon, where growth and yield of Cuthbert in 1931 were not satisfactory, the buds per foot for the lower part of the cane were recorded for several varieties. The Ranere had the fewest buds per foot, (3.0), and the Latham and Lloyd George the most, over 9 and over 8, respectively.

Although Lloyd George and Latham produced more buds per foot than other sorts in Oregon and the Latham more in Colorado, (2) vigorous 3-year-old Latham plants in Virginia (yield 4,536 pounds per acre) had as low as 4.7 buds per foot which indicates that mature plants may not have as many buds as the Colorado and Oregon records showed for 2-year-old plants. However, considering the num-

TABLE IV—NUMBER OF CANES PER PLANT, DIAMETER, AND BUDS PER FOOT OF BLACKBERRIES AND DEWBERRIES IN SELECTEDFIELD IN WESTERN OREGON

Variety	Canes per Plant	Base Diameter (Inches)	Buds per Foot, Base to Top														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total per Cane
Logan (dry)...............	16.4	0.41	4.2	3.5	5.0	5.2	5.2	5.4	5.7	5.2	5.2	5.3	5.0	5.0	5.3	6.0	74.1
Logan (irrigated)...........	21.3	0.40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Young (dry)...............	19.7	0.40	4.2	5.1	6.1	5.4	4.4	5.0	4.5	4.4	3.9	4.8	5.0	4.9	—	—	60.7
Himalaya (dry)............	5.8	0.76	2.5	2.6	2.9	2.9	3.2	3.3	3.5	3.3	3.0	3.4	—	—	—	—	30.6
Himalaya (dry)............	7.7	0.62	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Evergreen (irrigated).......	12.8	0.67	4.2	3.8	3.7	3.9	4.2	4.2	3.6	3.6	3.5	3.3	—	—	—	—	38.0
Evergreen (irrigated).......	9.2	0.57	3.8	4.2	4.2	3.7	3.8	3.4	3.1	3.0	2.9	2.6	2.5	2.6	2.6	—	42.4
Evergreen (dry)...........	12.0	0.55	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dellsweet (irrigated)........	10.4	0.56	3.4	3.4	3.4	3.4	3.0	3.0	3.0	2.6	2.4	2.4	2.4	2.4	—	—	34.8
Thornless Evergreen (dry)...	5.2	0.65	5.1	5.3	4.5	3.6	3.4	3.0	3.4	3.2	3.0	2.7	3.4	3.5	3.1	—	47.2

ber of buds produced by Lloyd George and Latham and the number and large size of berries produced by these sorts under favorable conditions, these varieties should be among the most productive.

Measurements of the canes of mature plants (except where stated) of blackberries and dewberries in well managed fields in western Oregon gave the records shown in Table IV.

The number of buds per cane and per foot of cane is much greater on mature plants of the Logan and Young than on mature plants of the Himalaya, Evergreen, Dellsweet (an Evergreen type), and the Thornless Evergreen, while the latter group has fewer and larger canes than the Logan and Young. In the planting at Corvallis, Oregon, less than 1 per cent of the buds of the Evergreen, about 11 per cent of the buds of the Logan, 9 per cent of the buds of the Farmer black raspberry, and 37 per cent of those of the Cuthbert failed to start in 1932.

Records of the seasonal growth of ten canes each of the Farmer black raspberry, Cuthbert red raspberry, the Evergreen and the Logan made in 1931 at Corvallis, Oregon, are shown by the graphs in Fig. 1.

The growth of all was satisfactory except that for Cuthbert it was not as great as is normally expected. By the end of the season many of the canes had been broken so that the number of canes averaged was, for the start and end of the season respectively, as follows: Logan, 60 and 18, Cuthbert 60 and 43, Farmer 8 and 4, and Evergreen 40 and 22.

Most of the growth in diameter of Farmer and Evergreen canes took place early in the season and of the Logan late in the season. Increase in length of cane was greatest for Farmer in the early part of the season but for Evergreen and Logan during the latter part. Cane growth of Cuthbert was relatively uniform during most of the season.

Some records taken at Corvallis indicate that the final size of the cane is rather largely determined early in the spring in which it starts growth. The diameters in inches of the new shoots were measured May 9 and again on November 9, 6 months later.

	May 9	*Nov. 9*
Cuthbert (large)	0.33	0.35
Cuthbert (small)	0.20	0.22
Logan (large)	0.42	0.44
Logan (small)	0.26	0.23
Evergreen (large)	0.61	0.63
Evergreen (small)	0.33	0.40

These shoots did not increase in diameter as much as those measured for the graph in Fig. 1, but diameter of cane in the spring largely determined diameter at the end of the season.

The number of good canes per plant, cane diameter and length, buds and laterals per foot, and berries per lateral of any variety are measures of vigor and of capacity for yielding. With healthy plants, distance between rows, temperature, soil moisture supply, low and

high humidities, length of day, and length of the growing season may change the relationship. Leaf rust, leaf spots, anthracnose, spur blight, and mosaic diseases, as well as insects, reduce plant vigor and

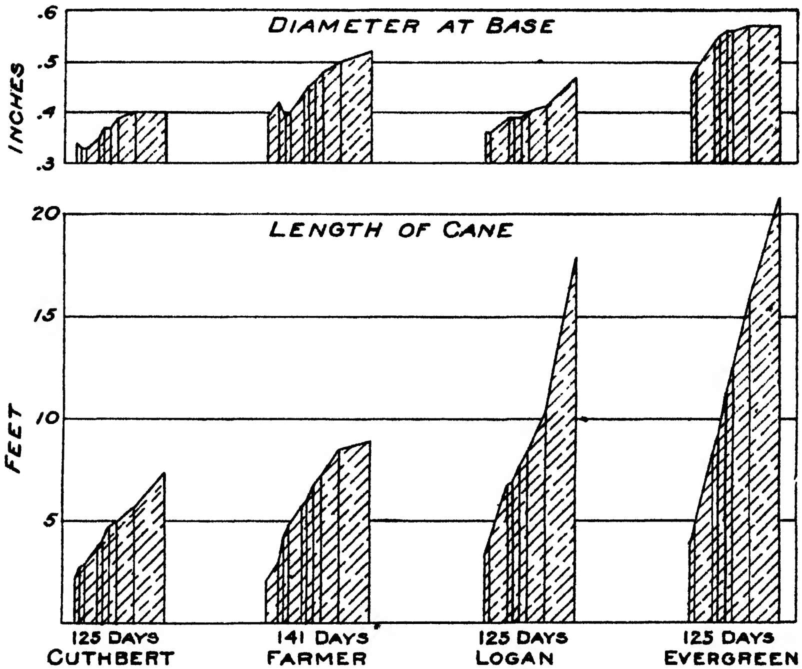

FIG. 1. Average cumulative growth during the summer of 1931 of vigorous canes of the Logan blackberry (12 canes per plant), Farmer black raspberry (4 to 10 canes per plant), Cuthbert red raspberry (6 to 9 canes per plant), and Evergreen blackberry (8 to 14 canes per plant). Farmer, May 7 to Sept. 24, others May 23 to Sept. 24.

complicate results, but in the selected fields from which the data in this paper were taken the effect of most of these pests was at a minimum. The records of cane growth under the above conditions, therefore, may to some extent be used to evaluate the effects of limiting conditions or cultural methods on cane growth. The conditions determining vigor and productiveness of buds and the causes of the buds not starting are suggested as worthy of further study.

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Preliminary Studies in the Fertilization of Red Raspberries[1]

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THE Rhode Island Station has studied the lime requirements of many kinds of plants in terms of their relative needs of lime, rather than in terms of lime applications for individual crops on a given soil, with results that were generally applicable, irrespective of the location where plants were to be grown. A similar study of the relative needs of some of the small fruits for nitrogen, phosphoric acid and potash yielded results reported in Bulletin 229 of this station. In this experiment red raspberries yielded with results from complete fertilizer applications considered as 100: with nitrogen omitted, 70 per cent; with phosphorus omitted, 82 per cent; and with potash omitted, 47 per cent. Since these findings differed widely from the commonly accepted views regarding nutrient requirements of the red raspberry, a more elaborate experiment on a somewhat different type of soil was laid out.

A stony pasture of moderate slope was selected on a piece of land recently acquired by the Station and an experiment using sixty 1/60-acre plats laid out with three levels of fertilization. Two seasons were occupied in preparing the land by clearing off rocks and growing a crop of buckwheat and a crop of rye to plow under each season. Four series of five plats each were allotted to each level of fertilization. Within each series one plat received a complete fertilizer of the same general composition as that used in the preliminary experiment; three plats received only two of the elements, one being omitted in sequence, and one check plat. In short, each treatment is represented by four plats, each fertilizer combination by 12 and there are 12 checks.

The soil, as indicated by cover crops used, is not uniform and the series of plats and corresponding checks were located in so far as

1 NP	3 PK	2 NK	3 NP	1 PK	O
1 NPK	O	2 PK	3 NPK	1 NK	2 NP
O	3 NK	O	3 NK	1 NPK	2 NK
1 NK	3 NPK	2 NP	3 PK	O	2 PK
1 PK	3 NP	2 NPK	O	1 NP	2 NPK
2 NK	1 PK	3 NP	2 NPK	3 PK	O
O	1 NK	3 NPK	2 NP	3 NK	1 NP
2 NP	1 NPK	O	2 NK	O	1 NPK
2 PK	O	3 NK	2 PK	3 NPK	1 NK
2 NPK	1 NP	3 PK	O	3 NP	1 PK

1 = 500 pounds per acre, 2 = 1000 pounds, 3 = 1500 pounds, O = check.

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possible so as to give the series of a given fertilizer level some of the better soil as well as some of the poorer. The sequence of plats within the series was arranged somewhat on the random basis. The following diagram indicates the arrangement of plats and the fertilizer treatment given. There were no buffer rows but rows in adjoining plats were 8 feet apart and the series were 12 feet apart.

From this planting we harvested a small crop in 1932, but since it was not considered representative, records of yields were not kept. In 1933 the plants bore a good crop. Table I gives the average 1933 yields for all plats under each treatment and for the three fertilizer levels and of the corresponding check plats.

TABLE I—AVERAGE YIELDS OF RED RASPBERRIES WITH VARIOUS FERTILIZER TREATMENTS

Treatment	Series 1 500 Pounds per Acre (Kgms)	Series 2 1000 Pounds per Acre (Kgms)	Series 3 1500 Pounds per Acre (Kgms)
No fertilizer	16.7 ± 1.4	9.7 ± 1.0	11.4 ± 1.0
No K	19.9 ± 1.7	17.4 ± 1.7	16.7 ± 1.5
No N	25.2 ± 2.1	25.3 ± 2.5	19.0 ± 1.7
No P_2O_5	26.2 ± 2.2	28.0 ± 2.8	31.2 ± 2.7
Complete	32.4 ± 2.7	35.6 ± 3.5	33.3 ± 2.9

Using the average yield of all the plats receiving complete fertilizer as the base, or 100, the check plats yielded 37 per cent, the no potash plats 53 per cent, the no nitrogen plats 69 per cent, and the no phosphoric acid plats 84 per cent as much fruit as the base plats.

It is somewhat surprising to find that there is not the uniform increase in yield from the 1000 pound and 1500 pound per acre applications which one might expect; in fact the total yields for the plats receiving 500 pounds per acre are highest and plats receiving 1000 and 1500 are slightly lower in the order given. Yields may have been influenced somewhat by the fact that in the fall of 1932 there were two excessively heavy rains which washed much of the finer soil from the plats to lower lands giving the remaining soil, especially on the higher lying plats, a distinctly stony and gravelly appearance in spite of the fact that the field had been carefully cleared of rocks that were exposed on the surface. Nevertheless, the average results as indicated by the table presented follow rather closely the results of the earlier experiment on the silt loam. Table II summarizes percentage results for the experiments on both types of soil.

TABLE II—FERTILIZER RESULTS WITH RED RASPBERRIES IN TWO SOILS

Fertilizer Treatment	First Experiment	Second Experiment
Complete fertilizer	100	100
Check plats	—	37
No potash	47	53
No nitrogen	70	69
No phosphorus	82	84

It is now too early to draw definite conclusions, even though trends are apparently in the same direction. It is proposed to record two or three more crops from the plats now planted and it would then be desirable to repeat the experiment once more on the land first used after that has been uniformly fertilized and planted to some other crop for 2 or 3 years, and finally to arrange for a general test of final conclusions in field trials on several types of soil. If, in addition, a similar type of experiment could be carried on at other stations it should eventually lead to a more definite knowledge of nutrient requirements of red raspberries.

A Rapid Method of Propagating Raspberries and Blackberries by Leaf-Bud Cuttings[1]

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THE method of rapid propagation of black raspberries by leaf-bud cuttings described in this paper was developed in connection with studies on anthracnose immunity conducted by the Pomology Subsection of the Iowa Agricultural Experiment Station Since tip layering is a rather slow method of increasing black raspberry plants, an attempt was made to use single or two-eye cuttings and also tip cuttings. These cuttings when placed in the propagating bench soon turned black and decayed without forming callus or roots. Finally a type of cutting was found which was successful. It consisted of a leaf with its axillary bud at the base of the petiole, the leaf being removed from the cane with a small heel of bark and wood attached. This is a greatly reduced form of single-eye stem cutting and can best be designated for the purposes of this paper as a "leaf-bud" cutting.

FIG. 1. Rooted cuttings of black raspberry (Quillen x Black Pearl) showing shoot growing from axillary bud at the base of the petiole.

The regeneration of roots or shoots from detached leaves has attracted the attention of botanists for a long time. An excellent summary of the literature on the subject has been given by Hagemann (1). Numerous plant species are capable of forming roots from detached leaves but comparatively few have the ability to initiate shoots also. Propagators have generally underestimated the possibilities of growing plants from leaves which will form roots because they have not taken into consideration the importance of the axillary bud at the base of the petiole which is essential in most cases for shoot formation.

[1]Journal Paper No. J143 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 291.

A previous paper by the senior author (3) reported that leaf-bud cuttings gave good results with a number of common greenhouse plants. Cuttings of this type have rarely been used for the propagation of woody plants, although Hunter (2) employed them in propagating certain types of citrus. The rapidity of multiplication from a limited number of stock plants possible with leaf-bud cuttings is evident from the fact that a single black raspberry cane which would form only one plant from each tip would furnish several dozen leaf-bud cuttings.

The technique used in making leaf-bud cuttings was very simple. A cut was made at the base of the petiole so that a small piece ot bark and wood was left to hold the axillary bud to the leaf petiole. When the heel was much over ½ inch long and ¼ inch deep, rooting was noticeably delayed. The appearance of the cutting just after rooting had occurred is shown in Fig. 1. Leaves from all portions of the cane were used except certain leaves at the base which in many cases showed senile changes. The stock plants from which the cuttings were taken stood in an unirrigated plot. A long season of dry weather induced a severe infestation of red spider mites, making it difficult to secure healthy leaves for use in the experiment. To obtain good healthy leaves with long petioles, propagators are advised to grow the stock plants under overhead irrigation under conditions of high fertility.

The leaf-bud cuttings were rooted in propagating frames of three types and all were shaded by one thickness of muslin. Two of the frames had no provision for bottom heat under the rooting medium; two had heat supplied by decaying stable manure; and two were heated electrically, through lead covered cable designed for hotbed heating, with temperatures controlled by thermostats. The frames were

TABLE I—Rooting Responses of Leaf-Bud Cuttings From Seedlings of a Black Raspberry Cross (Quillen x Black Pearl)

Cuttings Started	Unheated Frame				Manure Heated				Electrically Heated a' out 75 Degrees F)	
	Sand		Sand and Peat		Sand		Sand and Peat		Sand and Peat	
	Number Cuttings	Number Rooted	Number Cuttings	Number Rooted	Number Cuttings	Number Rooted	Number Cuttings	Number Roored	Number Cuttings	Number Rooted
June 23	50	0	50	28	—	—	—	—	—	—
July 14	50	6	50	30	100	9	—	—	100	46
July 24	100	7	100	12	100	100	100	100	100	100
Aug. 9	100	0	100	8	100	0	100	76	100	92
Aug. 24	—	—	—	—	—	—	100	100	100	100

covered with standard hotbed sash and closed tightly in order to maintain a high humidity.

The cuttings were inserted in rows in the rooting medium with the base of the petiole at a depth of about 1 inch. They were tamped in firmly, watered, and given the usual attention necessary for the handling of greenwood cuttings of nursery plants. The three rooting media used in these trials were: (a) tap water, (b) washed river sand, and (c) a mixture of three parts of sand to one of a brown moss peat. Where tap water was used, the cuttings were placed on a wire netting stretched over the top of a shallow metal tank in such manner that the leaf blades were kept above the surface of the water while the axillary buds and the lower parts of the petioles were submerged.

FIG. 2. Leaf-bud cutting of black raspberry two weeks after potting. Cutting made on June 23 and potted July 10. Photo taken July 24, 1933.

The cuttings were counted at the time of potting, which was between 2 and 3 weeks after the dates of the insertion in the frames.

The influence of the different media on rooting was very great. Some of the responses are shown in Table I. The use of sand alone seldom gave as good results as the mixture of peat and sand. In only one instance did the cuttings root well in sand; that was in a heated frame in which an unusually high humidity was maintained. The advantage of the peat over sand was doubtless due to the superior water-holding capacity of the former. The peat used in these experiments was obtained in northern Iowa and was slightly acid in reaction. The cuttings placed in tap water rooted freely and ultimately developed vigorous root systems and shoots, but the time elapsing before rooting started was usually two or three times as long as for the cuttings placed in the sand and peat mixture. Possibly these cuttings would have rooted more rapidly if the water had been well aerated. The reaction of the water was alkaline. The pH reading was uniformly 8.4 throughout the tests.

The use of bottom heat influenced results considerably. Some

comparisons of heated and unheated frames are presented in Table I. The temperatures in the electrically heated frames were recorded by soil thermographs. The heat was more uniform in these frames than in those heated by manure, but this did not seem to exert any measurable influence on the rooting of the cuttings. In one frame the temperature was maintained within a range of 70 to 75 degrees F and in the other within 75 to 80 degrees F. These different ranges in temperature did not cause any appreciable differences in rooting. From the results secured it may be stated that the use of bottom heat in the propagating frames was highly desirable under the conditions at Ames. It is probable that no sharply defined critical temperature is essential for the best rooting of the cuttings.

The temperature of the medium in the frames heated with decaying manure remained at about 75 or 80 degrees F for several weeks, but after that gradually decreased. There were sometimes wide fluctuations in temperature within the frame due to changes in the atmosphere outside. The temperatures in the unheated frames were usually from 5 to 10 degrees F lower than in those heated by manure.

FIG. 3. Young black raspberry plant of medium development grown from leaf-bud cutting made on June 23. Cutting potted July 10 and planted in field August 24, 1933. Photo taken October 24.

The cuttings rooted quickly and were usually potted within 2 or 3 weeks after they were placed in the frame. After potting they were put back in a covered and shaded frame and were gradually hardened off by increasing light and ventilation. Fig. 2 shows a potted cutting which has made some shoot growth. After a few weeks the roots filled the pots and heavy shoots had grown from the axillary buds. The plants were then transplanted to a field under overhead irrigation.

The cuttings placed in the frame on June 23 and July 14 were all potted before the end of July. When they were planted in the field, on August 24, the shoots were 3 to 10 inches long. The subsequent growth was rapid. When the plants were measured and photo-

graphed 2 months later (Fig. 3), all had from two to five canes each and the individual canes were often from 20 to 30 inches long. Plants from the same lot which were held in pots made very little top growth. This fact emphasizes the importance of early transplanting for material of this kind.

Repeated trials were made during the summer of 1933 with leaf-bud cuttings of the Chief and Latham red raspberries. Though all the combinations of conditions used with black raspberries were tried, none of these cuttings rooted though they invariably formed abundant callus.

The first attempts to root leaf-bud cuttings of blackberry were unsuccessful with sand as the rooting medium. Some success was obtained with the peat and sand mixture. Seventeen out of 50 cuttings placed in peat and sand over manure bottom heat on July 14 rooted and developed vigorous shoots and 11 out of 50 placed in tap water on the same date rooted. In no case, however, was rooting as rapid or free as with the black raspberry.

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Reaction of the Nutrient Medium as Affecting Growth of Strawberry Plants[1]

By J. Harold Clark, *N. J. Experiment Station, New Brunswick, N. J.*

ATTEMPTS of various investigators to determine the optimum reaction of the nutrient medium for the strawberry have included field plot experiments, pot experiments with soil, sand and water culture experiments. The soil experiments will not be reviewed here since the results are affected as much by the individuality of the soil as the particular requirements of the plant.

Morris and Crist (2) conducted two solution culture experiments with the strawberry. In the first the solution at pH 5.7 gave the best yield of plants, followed in order by pH 6.4, 7.5, 4.4, and 3.5. Plants in the last three solutions were distinctly inferior. In a second experiment, a different solution was used and the order of the various treatments from best to poorest was pH 6.0, 5.0, 4.0, 7.0, 8.0. Plants at pH 8.0 were very poor; those at pH 3.0 and 9.0 died.

Waltman (4) grew strawberries in sand culture using a solution containing both ammonium and nitrate nitrogen. In his experiments the yield of plants was greatest in the pH 5.0 treatment, followed in order by pH 6.0, 7.0, 8.0, and 4.0. Plants at pH 3.0 and 9.0 died.

Experimental Methods

Young runner plants of Howard 17 strawberry were removed from the field on October 4, 1932, and washed to remove all soil from the roots. All the leaves, except one per plant, were removed. Selected plants were then set in washed, white quartz sand, four plants to each 3-gallon glazed crock.

Nutrient solutions were supplied from elevated reservoirs, allowed to run through the sand and collected in reservoirs below. The rate of flow was adjusted by varying the height of the supply reservoir and the size of the capillary delivery tubes. During the experiment the flow was arranged so that 6 liters would run through in just less than 12 hours. Twice a day the solutions were poured back into the upper reservoirs or fresh solutions were substituted.

The large amount of solution used in proportion to the size of the plants made it seem feasible to run each lot of solution through more than once. Accordingly fresh solutions were applied every third or fourth day.

The Solutions

Previous experiments by the author have shown that the strawberry is quite sensitive to variations in salt proportions. In a triangle experiment conducted in 1929 using Type I (1) solutions, best growth was made with solution R1S5. This solution was selected,

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[1]Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

therefore, as the one on which to base a pH series since results with such a solution, proven suitable for the variety of plant to be grown, might well be different from those secured in a series based on a solution worked out for some other species

Solution R1S5, however, contains nitrogen only in the nitrate form. Work by Prianischnikow (3) and others has shown that the reaction at which plants make their best growth depends to a considerable extent on whether the nitrogen in the culture solution is present as ammonium or as nitrate. Accordingly, it seemed desirable to include an ammonium solution in the experiment. Since R1S5 is quite high in nitrogen, it was impractical to devise an ammonium solution which would contain an equivalent amount of nitrogen because of the danger of injury to the plants. The ammonium solution shown in Table I was used, the salt proportions being based on results of the nitrate triangle and results of work by others as to a safe concentration of ammonium sulfate.

TABLE I—Composition of Nutrient Solutions Showing Partial Volume Molecular Concentration of the Salts Used

Solution	KH_2PO_4	$MgSO_4$	$CaCl_2$	$Ca(NO_3)_2$	$(NH_4)_2SO_4$
R1S5	.0022	.0043	—	.0108	—
Ammonium	.0022	.0043	.00864	—	.0014
Minus-N	.0022	.0043	.0108	—	—

Iron was added as needed in the form of ferrous sulphate. Manganese and boron were each added at the rate of .25 mg per liter of solution. All solutions were made up from distilled water and C. P. chemicals.

All plants received the minus-N solution for the first 13 days. After this period half the plants received the R1S5 solution and the other half received the ammonium solution. Each of the two groups was further subdivided into 6 lots of four pots each, each lot receiving its solution at a different pH value. The reactions of the solutions used in the different treatments are shown in Table II.

Maintaining the Desired Hydrogen-Ion Concentrations

It was realized at the start that the solutions, containing a low concentration of potassium phosphate, were poorly buffered. It did not seem feasible, however, to use higher concentrations of potassium phosphate since in the triangle experiment the high phosphate solutions invariably gave poorer growth than the low phosphate solutions.

The reaction of the solution bathing the roots of the plant is of primary importance and not the reaction of the solution as it is applied. Many experiments have shown that the reaction of a solution not well buffered may be greatly changed by the differential absorption of ions by the roots of plants. In such cases the pH of the solution about the roots is far from constant and any results secured are difficult to interpret.

In this experiment it was decided to use quantities of solution large enough so that absorption by the roots could not materially change the reaction of the mass of the solution. Tests showed that a flow of 6 liters per pot each 12 hours was sufficient to maintain the reaction so that the pH of the drip was seldom more than .2 of a pH unit greater or less than that of the solution as applied. Microchemical tests of the solutions on the surface of the absorbing roots showed that the pH did not vary greatly from that of the solution, as it was applied, except in the following cases. The pH at the root surface in the most acid solution was about .4 to .6 of a pH unit more alkaline than the solution as it was applied, and the pH at the root surface in the least acid solution was sometimes as much as 1 pH unit more acid than the solution as applied, but averaged only about .2 of a pH unit more acid.

The solutions were adjusted to the desired reaction by the addition of N/2 H_2SO_4 or N/2 KOH. Tests for hydrogen-ion concentration were made colorimetrically, using the Hellige Klett color comparator. Each reservoir of solution was tested and adjusted daily.

Growth Responses

At the end of the 13-day period during which a minus-N solution was applied the plants were making root growth. A new leaf had developed on each plant and in some cases had reached a width of 1.5 inches. The color of these new leaves was yellowish-green.

Five days after the complete solutions were started, the plants were showing the effects of nitrogen by turning darker green. Seven days after the complete solutions were started, the plants growing at pH 3.4 and 4.0 in both the nitrate and the ammonium solutions were noticeably lighter in color than the others.

Forty-one days after the differential treatments were started there were very marked differences in appearance of plants. All were still alive except one plant in the ammonium pH 3.4 treatment. Space will not permit a detailed description of the plants in each treatment but the following general description together with the data in Table II will give an idea of the growth responses.

All of the plants receiving a solution containing nitrogen as nitrate were making a practically normal growth. Plants at pH 3.4 were darkest in color but were a trifle small and showed a slight burning at the edges of the older leaves. Plants at pH 6.4 had slightly smaller leaves than any other treatment in this series. One leaf on one plant showed some chlorosis. The plants in the other nitrate treatments were all making good growth and varied only slightly in size.

There was much greater variation in the plants receiving nitrogen as ammonium. Plants at pH 3.4 were by far the smallest and poorest in the entire experiment. All leaves except the youngest were badly burned at the margin with as much as half the area of individual leaves being brown. The green portion of the leaves showed the lightest color of any treatment. Plants at pH 4.0 showed slightly less injury; at pH 4.6, slightly less than at 4.0; at 5.2, slightly less

than at 4.6. The plants at 5.8 and 6.4 were free from injury and appeared to be the most vigorous of any in the experiment. Slight chlorosis was beginning to develop on some leaves in the pH 5.8 and 6.4 treatments.

All the ammonium plants had slightly shinier and more flaccid leaves than the nitrate plants.

Root Development

The plants were harvested 41 days after the differential treatments began. All of the plants had made considerable root development although in certain treatments this growth had probably been made during the time the minus-N solution was being applied.

Roots of all the plants from the nitrate treatments were white. All were long and fibrous except those from the pH 3.4 treatment which were very stubby and crinkled.

Roots from ammonium pH 6.4, 5.8, and 5.2 treatments were white, fibrous, and apparently normal. Roots from the pH 4.6 treatment were white, rather extensive, but a trifle crinkly. The roots of plants from the pH 4.0 treatment were short, rather stubby, and more crinkled. Those from the pH 3.4 treatment were short, many dead, and those that were alive and functioning were very stubby and crinkled.

Size of Plants

Table II indicating the relative size of plants produced by the different treatments is largely self explanatory. The high percentage of dry weight of the ammonium pH 3.4 and 4.0 plants is due largely to the fact that there was considerable dead tissue present when the plants were harvested.

TABLE II—Strawberry Plants Supplied with Complete Nutrient Solutions at Different Hydrogen-Ion Concentrations. Average Weights of Plants

Source of Nitrogen	pH	Number Plants	Average Green Weight (Gms)	Per cent Dry Weight	Average Dry Weight (Gms.)
Calcium Nitrate.....	3.4	14	8.85	19.19	1.699
Calcium Nitrate.....	4.0	15	11.31	18.98	2.146
Calcium Nitrate.....	4.6	15	13.41	19.97	2.679
Calcium Nitrate.....	5.2	15	12.44	20.81	2.589
Calcium Nitrate.....	5.8	15	10.62	20.63	2.191
Calcium Nitrate.....	6.4	14	9.59	20.74	1.989
Ammonium Sulfate..	3.4	14	7.17	22.89	1.641
Ammonium Sulfate..	4.0	15	8.09	22.40	1.813
Ammonium Sulfate..	4.6	15	9.75	19.42	1.894
Ammonium Sulfate..	5.2	15	9.15	20.97	1.918
Ammonium Sulfate..	5.8	15	10.97	20.25	2.222
Ammonium Sulfate..	6.4	14	11.07	20.80	2.303

Green and dry weights were obtained for leaf blades, petioles, crowns, and roots. Blades and petioles of the best ammonium treatment averaged heavier than in the best nitrate treatment. In the best nitrate treatment, pH 4.6, however, the roots averaged 1.131 gms dry weight per plant, whereas in the best ammonium treatment, pH 6.4, the roots averaged only 0.704 gms dry weight per plant. Weight of crowns probably depended more on the weight at the time the experiment started than on the differential treatments as these organs increase in size very slowly. The crowns of the nitrate pH 4.6 treatment were largest averaging 0.393 gms dry weight per plant, those of nitrate pH 5.2 averaged 0.358 gms and those of ammonium pH 6.4 were third highest, averaging 0.354 gms.

Summary

Plants of Howard 17 strawberry grown in sand culture, made the greatest total growth when the nutrient solution was maintained at pH 4.6 if the nitrogen was supplied in the form of nitrate and at pH 6.4 if the nitrogen was supplied in the form of ammonium.

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Nutrition of Strawberry Plant Under Controlled Conditions: (a) Effects of Deficiencies of Boron and Certain Other Elements: (b) Susceptibility to Injury from Sodium Salts

By D. R. HOAGLAND and W. C. SNYDER, *University of California, Berkeley, Calif.*

(a) EFFECTS OF DEFICIENCIES OF BORON AND CERTAIN OTHER ELEMENTS

IN the course of a general investigation of diseases of the strawberry in California, H. E. Thomas and W. C. Snyder of the Division of Plant Pathology, observed symptoms apparently related to soil conditions. Water culture experiments were undertaken with the hope of developing similar symptoms under control. The strawberry is well adapted to such experimentation.

Plants were grown in 20-gauge black steel tanks (coated with asphalt paint) of the following dimensions: length, 30 inches; width, 12 inches; height, 8 inches; capacity, 45 liters. In the first experiment, covers for the tanks were in the form of wooden trays with screen bottoms. Burlap was placed over the screens and then a layer of saw-dust, in which the plants were set. In later experiments, a more satisfactory technique was developed, using black steel covers fitting over the tanks. These covers were drilled with 10 uniformly spaced holes of 2 - $\frac{9}{32}$ inches diameter, each fitted with a cork, in which a large hole was bored. Plants with well-developed root systems were removed from flats of sandy soil and the roots washed as free as possible of adhering particles. The plants were then transferred to the culture solutions, one plant being inserted in each cork. After roots had made sufficient development, the culture solution was lowered several inches below the top of the container so as to facilitate aeration. Banner and Nich Ohmer varieties were grown in the same tank and in one experiment Klondike variety was also used. In the second experiment, dealing with supplementary elements, most of the treatments were carried out in duplicate, with consistent results.

The composition of the culture solution was: KNO_3, .005 M.; $Ca(NO_3)_2$, .005 M.: $MgSO_4$, .002 M.; KH_2PO_4, .001 M. Iron tartrate solution, 0.5 per cent was added as required in the proportion of 1 cc per liter of solution. Solutions were changed once or twice during the experiment. To certain tanks, additional elements were added in minute quantities—in the first experiment in the form of a general supplementary solution containing Al, I, Br, Ti, Sn, Li, Mn, B, Zn, Cu, Ni, Co (Solution A, Table I).

After 6 to 8 weeks, plants growing in culture solutions without the supplementary solution manifested striking symptoms of malnutrition. Leaves were severely deformed, dwarfed, cupped upward, puckered and generally brown at the tips. Runner plants were greatly retarded in growth, with leaves dwarfed and showing other symptoms

FIG. 1. Plants in nutrient solution without and with supplementary solution. (Deficiency of boron is primarily involved in this experiment.)

FIG. 2. Symptoms of boron deficiency, showing effects on leaf size.

FIG. 3. Symptoms of boron deficiency, showing characteristic changes in leaf structure.

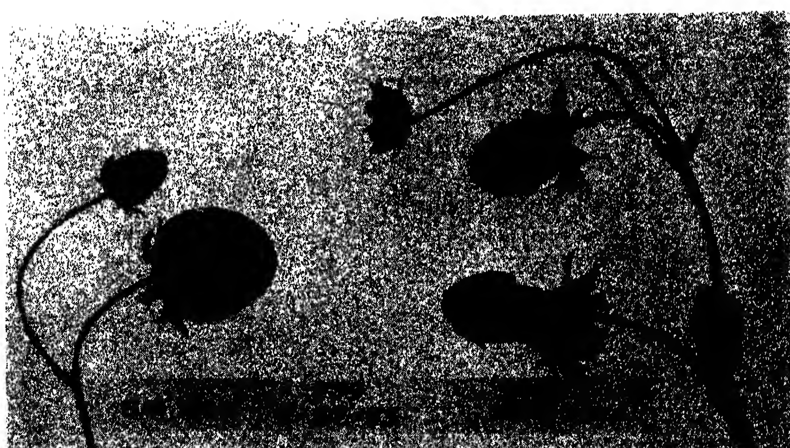

FIG. 4. Effect of boron deficiency on fruit.

as noted above. Rootlets were stunted. The addition of manganese to the culture solution did not appreciably improve the plants.

Another experiment was made with different combinations of elements to determine which element of the supplementary solution was of primary importance. A prediction was verified that deficiency of boron would account for the major symptoms of malnutrition present in the first experiment. Nevertheless, plants receiving only boron and manganese were distinctly inferior to plants receiving the entire supplementary solution, in color, general appearance and development of runner plants. Copper or zinc, or both, also seemed to be needed, and perhaps still other elements. In one tank, an enlarged supplementary solution was employed, including, in addition to the elements already mentioned, As, Ba, Cd, Bi, Rb, Cr, F, Pb, Hg, Mo, Se, Sr, W, V (Solution B, Table I). From general ap-

TABLE I—COMPOSITION OF SUPPLEMENTARY NUTRIENT SOLUTION*

Solution A		Solution B	
Salt	Grams	Salt	Grams
$Al_2(SO_4)_3$	1.0	Solution A plus the following:	
KI	0.5	As_2O_3	0.1
KBr	0.5	$BaCl_2$	0.5
TiO_2	1.0	$CdCl_2$	0.1
$SnCl_2.2H_2O$	0.5	$Bi(NO_3)_2$	0.1
LiCl	0.5	Rb_2SO_4	0.1
$MnCl_2.4H_2O$	7.0	$KCrO_4$	0.5
H_3BO_3	11.0	KF	0.1
$ZnSO_4$	1.0	$PbCl_2$	0.1
$CuSO_4.5H_2O$	1.0	$HgCl_2$	0.1
$NiSO_4.6H_2O$	1.0	MoO_2, 85 per cent	0.5
$Co(NO_3)_{26}.H_2O$	1.0	H_2SeO_4 (Sp. gr. 1.4)	0.1
		$SrSO_4$	0.5
		H_2WO_4	0.1
		VCl_2	0.1

*Made to 18 liters; 1 cc of solution used for each liter of nutrient solution.

pearance, both observers obtained the distinct impression that the plants receiving this solution were superior to all others. The weights of the plants from the minus-boron solution were significantly lower than those from the plus-boron solutions, but a requirement for other supplementary elements could not be demonstrated by yield data, since variability was high. The concentration of boron in the culture solutions receiving boron was approximately 0.1 p. p. m. This prevented completely boron deficiency symptoms in plants grown in spring, but not in summer. The upper limit of tolerance for boron has not yet been determined, but the preliminary indications are that this will not be very high.

Earlier investigations on the essentiality of boron for plant growth were conducted under highly controlled conditions, with rigorous precautions for the exclusion of impurities from culture solutions. The fundamental fact was established that boron was an essential

element, but it remained questionable whether a deficiency of boron ever occurred under the usual conditions of plant culture experiments. Later experiments on tomato and other plants have shown that boron supplied as an impurity may be inadequate, and the suggestion arises from certain observations that even under field conditions it is not impossible that deficiency of boron may limit plant growth in special cases. Our experiments indicate that the strawberry plant is one which requires much more than a trace of boron for normal growth.

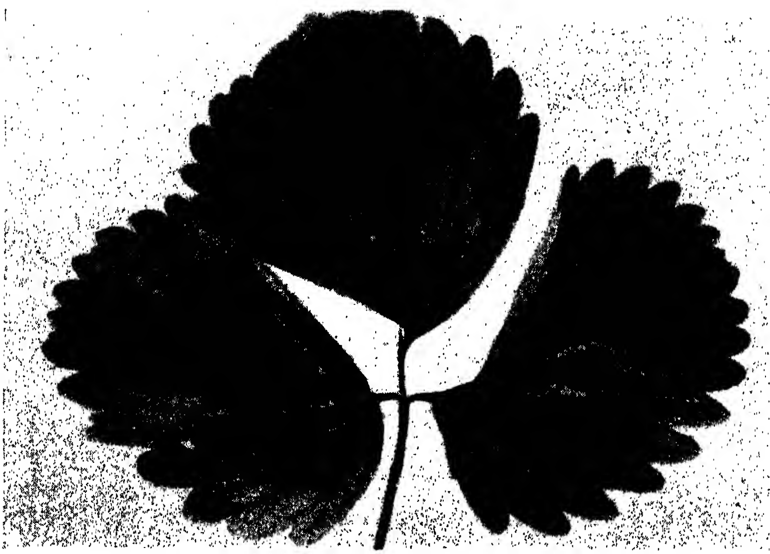

FIG. 5. Symptoms of potassium deficiency on plants first grown in a complete culture solution and then changed to a solution containing no potassium.

In certain areas in California, strawberry plants growing in the field sometimes show moderately severe leaf symptoms similar to those produced by boron deficiency under greenhouse conditions although direct evidence, proving that the cause is the same, is not available. Since the boron requirement of the strawberry plant is appreciable, it will be of interest to determine whether response can ever be obtained from applications of boron in the field. Such experiments should take into consideration resistance of plants to root rots, associated with fungus attacks. An adequate supply of boron is required for the development of healthy roots.

In one experiment, an incidental observation was made that plants growing in the culture solution to which was added the enlarged supplementary solution (Solution B), were almost completely free of mildew and of red spider, whereas plants without any supplementary treatment were highly susceptible to such attacks. Plants with partial supplementary treatment were attacked in intermediate degree. It is

not desired to claim that this incidental observation has any general significance, but further experimentation is suggested.

Effects of Potassium and Phosphate Deficiencies:—Plants were grown for several weeks in complete culture solutions, including supplementary solution, and then transferred to solutions without potassium or without phosphate. Symptoms of phosphate deficiency included the development of purple tints in the leaves, and were very much like symptoms of phosphate deficiency shown by many types of plants. The potassium deficiency symptoms presented certain special characteristics. Marginal scorch was not prominent, injury being first manifested by bronzing and necrosis of petiole and base of leaf, a somewhat different type of symptom from that described by Davis and Hill (1). Banner plants showed more severe injury than Nich Ohmer.

Varietal Responses:—Regardless of treatment, Banner variety always produced more extensive root systems than Nich Ohmer, but the former was much more susceptible to injury and inhibition of growth resulting from nutrient deficiencies, especially of boron. Klondike variety was least susceptible to this deficiency. Differences in root development under water culture conditions may indicate that oxygen requirements of different varieties vary. In future experiments, effects of forced aeration of the culture solution should be studied.

(b) Susceptibility to Injury from Sodium Salts

Certain types of injury under field conditions suggested "alkali" conditions and the tolerance of strawberry plants to sodium salts was investigated by water culture methods already described. Nich Ohmer variety was highly sensitive to even moderate concentrations of sodium salts (100 to 500 p. p. m. of solution). Toxic effects were produced by both sodium sulphate and sodium chloride, equivalent concentrations of sodium having similar effects, at least for the Nich Ohmer variety. The principal symptom of injury was a marginal burning, which sometimes spread until the whole leaf was killed. Roots became brown in color. There occurred a marked accumulation of sodium in injured leaves, and also in root tissues. From the sodium chloride solutions, chlorine accumulated in leaves in greater equivalent amounts than sodium, with one exception. The excess of chlorine accumulated by leaves of Banner plants was striking (Table II). However, observations on the sensitive Nich Ohmer variety show that severe injury may occur in the absence of chlorine. The highest accumulations of chlorine may have had a toxic effect on Banner plants. Nich Ohmer variety had a higher capacity for sodium accumulation than Banner, as judged by leaf analyses.

Plants grown in solutions containing small amounts of sodium bicarbonate showed marked root necrosis (black or brown roots) and some yellowing of foliage, but less leaf scorch than was produced by sodium chloride or sulphate. The pH of the toxic solutions was within the range of 7.3 to 8.2.

The Nich Ohmer variety was much more sensitive to injury from all sodium salts than the Banner, the reverse of the relation shown in response to nutrient deficiencies.

TABLE II—ACCUMULATION OF SODIUM AND CHLORINE BY STRAWBERRY PLANTS (LEAVES)

Salt Added	Concentration p.p.m. of Solution	Condition of Leaf	Analysis of Leaf Per cent Dry Weight		Analysis of Root Per cent Dry Weight	
			Na	Cl	Na	Cl
			Nich Ohmer Variety			
None	——	No injury	0.02	0.18	0.007	0.12
NaCl	500	No injury	0.15	0.50	——	——
NaCl	500	Injured	0.34	0.68	——	——
NaCl	1000	No injury	0.16	0.36	——	——
NaCl	1000	Injured	0.70	0.92	——	——
NaCl	2000	No injury	0.26	0.54	.68	1.39
NaCl	2000	Injured	0.94	2.51		
Na_2SO_4	600	No injury	0.31	0.10		——
Na_2SO_4	600	Injured	0.44	0.07	——	——
Na_2SO_4	1200	No injury	0.44	0.11	——	——
Na_2SO_4	1200	Injured	0.72	0.13	——	——
Na_2SO_4	2400	No injury	0.29	0.10	.71	0.16
Na_2SO_4	2400	Injured	0.85	0.18		
			Banner Variety			
None	——	No injury	0.03	0.04	0.06	0.11
NaCl	500	No injury	0.06	0.60	——	——
NaCl	1000	No injury	0.12	1.15	——	——
NaCl	2000	No injury	0.18	1.32	0.95	1.20
NaCl	2000	Injured	0.29	2.41		
Na_2SO_4	600	No injury	0.06	0.08*	——	——
Na_2SO_4	1200	No injury	0.10	0.06	——	——
Na_2SO_4	2400	No injury	0.23	0.06	0.78	0.24

*Cl present in plants from sodium sulphate treatment was derived from impurities present in salts.

Little doubt exists that injury to strawberry plants from sodium salts occurs under certain field conditions. This is evidenced by symptoms similar to those described above and also by analyses of leaves, soils, and irrigation waters. The general conclusion may be drawn that growing strawberry plants in beds with heavy irrigation is conducive to the accumulation of sodium salts, and that some varieties are highly sensitive to even moderate concentrations of sodium. An alkaline reaction accompanying the presence of sodium bicarbonate also seems to be more injurious to the strawberry than to many other crops.

Investigation of the relation of soil conditions to varietal characteristics and to fungus attacks may become of importance from the point of view of field practice. The methods of water and sand culture are of great assistance in such investigations.

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Strawberry "Black Root" Injury

By R. H. Roberts, *University of Wisconsin, Madison, Wisc.*

SOME springs strawberry plants show some to much discoloration of the root and interior of the crown. These plants grow poorly after transplanting as well as yield small crops in drought seasons. The general distribution of the trouble in 1932 as regards soil, exposure, variety, and location suggested a climatic injury, apparently late fall cold. Mulching at different times to correspond with lowering temperatures from early October until December 1, gave the following results: After a temperature of 7 degrees F on November 19 the percentage of Dunlap roots showing some discoloration on large, medium, small, and very young plants was 3.6, 13.6, 50.6, and 94.8. Plants which were mulched before a temperature of 20 degrees F was reached showed no clear cut injury. Sectioning of the roots disclosed that many roots on the large plants had evidence of internal injury although appearing uninjured from external observation. The variety Premier showed more injury than Dunlap. It is believed this is not a matter of less hardiness, but is due to the thin row common to this kind and to consequent poor self-protection.

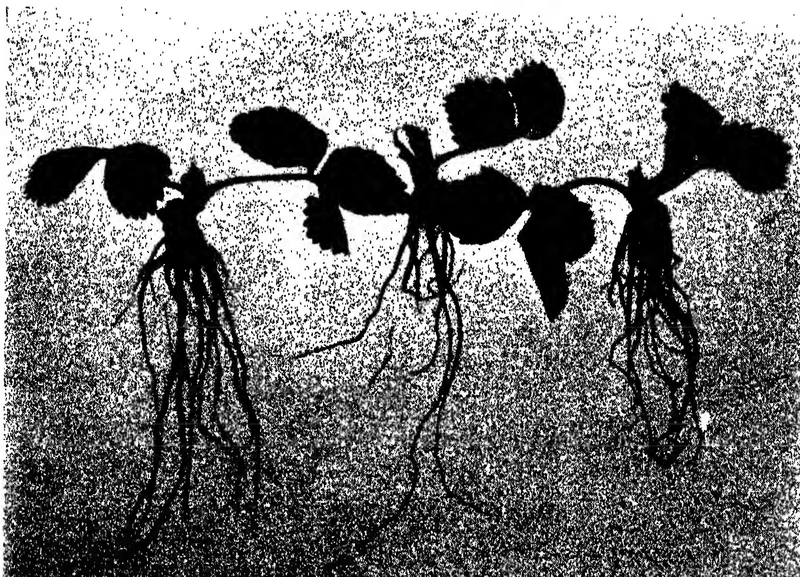

Fig. 1. Photograph of young plants dug in late May, 1933. Left: Mulched Nov. 12, 1932. Center and right: Unmulched plants showing serious root injury. Older plants may show only "rusty" colored roots due to internal injury but no apparent external breakdown.

Marked injury occurred again November 15, 1933, following a temperature drop to 6 degrees F. Traces of injury were apparent after a 17 degree temperature, November 10. Again, plants mulched previous to a temperature of 20 degrees were not injured.

A discussion of the practical phases of the problem appears in Wisconsin Agricultural Experiment Station Stencil Circular 139, September, 1933.

Dr. G. W. Keitt of the Plant Pathology Department has kindly given us the following summary of the results of isolation studies made in his laboratory from our samples of injured and uninjured roots collected in January (2), February, and May, 1933: Between 18 and 20 fungi were found, including species of Fusarium (4), Mucor (2), Rhizopus (1), Alternaria (1), Penicillium (4), Aspergillus (1) and Macrosporium (1). The only fungus (unidentified) which appeared very consistently (from isolution Feb. 4, 1933) developed on uninjured as well as blackened root segments with cortex but did not develop on segments of stele with cortex removed. The pieces of roots with cortex removed gave either no fungus growth at all or some common contaminants from *ends* of segments cut through by scissors.

Those fungi (and bacteria) which developed from roots appeared on control or uninjured roots almost as often as on blackened roots. It would appear from these preliminary studies that no fungus isolated by the methods used is consistently associated with the injured roots.

Effects of Fertilizer on the Native Maine Blueberry

By F. B. Chandler and I. C. Mason, *Experiment Station, Orono, Me.*

THOUGH the blueberry industry may be justly considered a horticultural industry, it differs greatly in most regions from those with which we are most familiar, as expressed by Hildreth (2). Pruning is done only once in 3 years and is accomplished by burning off all of the plant above the ground. This gives a year without a crop, a year with a large crop commonly called first crop, and the third year which usually gives a yield of a quarter to a half the first crop. In the nutrition studies, on which this is a partial report, fertilizer was applied to wild blueberry plantings, (*Vaccinium pennsylvanicum*), in the spring of 1928 under the direction of Dr. A. C. Hildreth. Since he left Maine these plots have been continued and a second application of fertilizer was made in 1931.

On one series of plots, studies were made using NPK, NP, NK, and PK in comparison with untreated areas. Sulfate of ammonia was applied at the rate of 300 pounds per acre, superphosphate at the rate of 750 pounds per acre and muriate of potash at the rate of 250 pounds per acre. The applications were made in the spring 1 year before the pruning. The soil was of mineral origin very low in organic matter and available nitrogen. On these plots the pH of the soil before treatment was 4.7 to 5.1 and has changed only slightly up to 1933. The available phosphorous in the soil of these plots was very low, ranging from 2 to 4 p. p. m. and has been increased to 10 to 25 p. p. m. on the plots receiving phosphorous in the fertilizer.

Increased growth and better color of foliage was obtained on all plots receiving nitrogen, while the plants on the plots receiving only phosphorous and potash were not much better than those on the untreated plots. Increased yields of fruit were obtained at all three harvests from the plots receiving nitrogen and at two harvests from those plots receiving phosphorous and potash. The complete fertilizer gave an increase of 128.6 per cent for the third harvest (after second application of fertilizer). On some plots the fertilizer treatments stimulated weed growth to such an extent that the competition for light and nutrients resulted in a decrease in blueberry yields.

The berries from these plots were studied for total acidity, amino nitrogen, total nitrogen, reducing sugars, non-reducing sugars, and acid hydrolizable material. Total acidity was determined as titratible acidity and showed that berries from plots receiving nitrogen were more acid. Amino nitrogen determinations by the Van Slyke method gave the following percentages (expressed fresh weight basis): Check .098, NP .081, NK .071, NPK .071, and PK .050. Total nitrogen determinations by the Kjeldahl method gave the following percentages: PK .091, NPK .088, check .085, and NP .0844. By the Quisumbing and Thomas method the percentages of reducing sugars were determined as follows: check 8.99, NK 8.30, NP 8.04, PK

7.92, and NPK 7.72. By acid hydrolysis we found non-reducing sugars as follows: PK .645, NPK .560, NK .244, NP .215, and check .181. The acid hydrolizable material was found to vary from .846 to 1.06. In summarizing our work on these plots we found that fertilizers carrying nitrogen stimulated growth, increased the number of fruit buds per stem, and gave greater yields than untreated plots. All fertilizer treatment induced a decrease in reducing sugars and minor changes in non-reducing sugars and nitrogen. Cochran and Webster (1) in their analysis of strawberries from different fertilizer plots obtained similar results for acidity, reducing sugars and non-reducing sugars.

Studies made on another series of plots indicated that the pH of the fruit varied from 3.63 to 4.11, fish meal giving the lowest and sulfate of ammonia the highest. In this series manganese sulfate gave a decrease in yield. The fruit on the manganese treated plot had a pH similar to the check, and amino and total nitrogen somewhat higher than the check. Manganese was used because it has some possibility of killing a serious weed (*Kalmia angustifolia* L.) without destroying the blueberry.

As the trend is increasingly in favor of the frozen and fresh fruit marketing of berries rather than of canning, an attempt was made to study the shipping quality of berries from some of the plots, but due to variability of the results they will not be published until more information is obtained. Amount of rainfall and method of picking, as well as ability of individual pickers, are important factors which must be studied in conjunction with fertilizers upon shipping quality.

Grading studies showed very little difference in size of berry due to fertilizer treatment.

Although fertilizer is not used on any of the commercial areas in the state, it would seem that it could be applied with benefit where it will not stimulate weed growth. Though fertilizers slightly decrease the reducing sugars and increase the acidity a little, this would not make the fruit less desirable.

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Yield Relationships on Terminal Growths in York Imperial Apples

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BIOMETRICAL analyses of relationships between fruit yields and growth characters in the apple tree have been reported upon by several investigators. Analyses of this nature are presented by Collison and Harlan (3), by Cooper (4), by Sax and Gowen (8), by Waring (9) and by HofMann (5).

Justification for such investigation is suggested in the conclusions of Waring (9) and very recently by those of Anthony (1). Certain phases of curvilinear relationship were brought out by HofMann (6) which prompted this subsequent study.

Material Used[1]

During the harvest season, length and diameter measurements of the last year terminal growths together with their respective current season linear extension and their fruit yields were made on York Imperial apple trees. The fruits were measured for weight and size. Three hundred measurements were made in 1929; one hundred in 1930; two hundred in 1931; and three hundred in 1932. These trees which are in the experimental orchards of the Virginia Agricultural Experiment Station at Blacksburg, Virginia, were 18 years old when the first set of measurements were made.

Relationships as Indicated by the Correlation Coefficients That Were Secured in These Studies

When length of terminal growths of the previous season was arrayed with the fruit yield in the current season on these individual terminal growths, the correlation coefficients that were secured are: 0.5091 ± 0.0288 for 1929; 0.4236 ± 0.0554 for 1930; 0.7003 ± 0.0243 for 1931; and 0.3525 ± 0.0341 for 1932. In every case there is statistical significance.

When diameter of terminal growths of the previous season was arrayed with the fruit yield in the current season on these individual terminal growths, the correlation coefficients that were secured are: 0.5246 ± 0.0282 for 1929; 0.5494 ± 0.0471 for 1930; 0.7340 ± 0.0220 for 1931; and 0.1178 ± 0.0384 for 1932. With the exception of 1932, all of the coefficients are statistically significant. Because of the consistent statistical significance for the other seasons the coefficient for 1932 can be accepted as biologically significant.

When length of linear extension on terminal growth of a previous season was arrayed with the fruit yield of the current season on the individual terminal growth, the correlation coefficients that were

[1]The records in this presentation were made by Mr. R. C. Moore, Assistant Horticulturist, under the supervision of the author.

secured are: 0.5263 ± 0.0282 for 1929; 0.4242 ± 0.0553 for 1930; 0.4420 ± 0.0384 for 1931; and 0.4496 ± 0.0314 for 1932. In every case the coefficients are statistically significant.

When diameter of linear extension on terminal growth of the previous season was arrayed with the fruit yield of the current season on the individual terminal growth, the correlation coefficient secured was 0.4538 ± 0.0308 for 1929; 0.2375 ± 0.0637 for 1930; 0.3056 ± 0.0432 for 1931; and 0.0978 ± 0.0386 for 1932. The coefficients which are statistically significant for 1929 and 1931 and almost so in 1930 may be considered significant biologically.

When length of terminal growth of a previous season was arrayed with the average size of fruit in the current season on the individual terminal growth, the correlation coefficients that were secured are: —0.3013 ± 0.0354 in 1929; —0.1205 ± 0.0664 in 1930; —0.538 ± 0.0466 in 1931; and 0.1183 ± 0.0384 in 1932. In all cases except for 1932, the coefficients are negative and in 1929 and 1931 they are statistically significant.

When diameter of terminal growth of a previous season was arrayed with the average size of fruit in the current season on the individual terminal growth, the correlation was —0.2175 ± 0.0371 for 1929; 0.1027 ± 0.0657 for 1930; —0.1577 ± 0.0459 for 1931; and 0.1891 ± 0.0376 for 1932. A statistically significant negative correlation coefficient was found for 1929 and almost so for 1930. A statistically significant positive correlation coefficient was found for 1932.

When length of the terminal growth of a past season together with that of its linear extension was arrayed with the average weight per apple on individual terminal growths of a past season, the correlation coefficients that were secured are: —0.2309 ± 0.0369 for 1929; 0.0390 ± 0.0673 for 1930; and —0.1636 ± 0.0464 for 1931. The coefficients for 1929 and 1931 are negative and statistically significant.

When diameter of the terminal growth of a past season together with that of its linear extension was arrayed with the average weight per apple on individual terminal growths of a past season, the correlation coefficients that were secured are: —0.0567 ± 0.0388 for 1929; 0.027 ± 0.0657 for 1930; —0.0570 ± 0.0476 for 1931; and —0.4053 ± 0.0325 for 1932. Negative coefficients were found in all these years except for 1930. The coefficient in 1932 was negative and statistically significant.

The negative relationships shown are rather apparent as the longer growths tend to have the larger number of apples and where the number of apples become larger the chances are greater for the average weight of apple to be less.

Correlation Ratios and Application of Blakeman's Test for Linearity

The correlation coefficients that were secured show statistical significance in the relationship for 1929, 1930, 1931, and 1932 between length or diameter of a terminal growth and the fruit that is borne on

it in the following season. To get a more accurate degree of the relationship, the so-called Blakeman test for linearity was applied in some of the data referred to in the earlier part of this paper.

According to Blakeman (2) "one of the things to be determined in any frequency distribution between two characters, say x and y, is whether the regression y on x is linear or non-linear." It is pointed out that for linear regression the difference between the square of the correlation ratio and the correlation coefficient is 0 (zero) or, putting it in the form of Blakeman $\eta^2 - r^2$ equals 0. Blakeman explains "the necessary and sufficient conditions for linearity" as follows: "Now in actual distribution, we shall not expect to find this result exactly zero, but even when the regression of y on x is linear we shall expect this difference to be influenced in the usual way by the fact that our material is only a random sample of a general population. Thus, in all statistical tests having found this difference to have a certain positive value, we want to know if these values are such as might arise from errors due to random sampling from a general population whose regression is linear, or whether the values are such as to indicate significant non-linearity." Thus, a necessary and sufficient condition for linearity as explained by Rietz (7) is that "$\eta^2 - r^2$ shall differ from zero by an amount not greater than the fluctuations due to random sampling."

If $\eta^2 - r^2$ or Zeta is 2.3 times or more than its standard error it is statistically significant and the correlation coefficient or r fails to describe the relationship. The relationship is thus a non-linear or a curvilinear one.

Correlation ratios are shown usually as y on x and x on y, but to simplify this discussion the regression of y on x or fruit yield on terminal growth alone will be selected, with the fruit yield the ordinate and the terminal growth the abscissa. For the 4 years the correlation ratios are respectively 0.5865; 0.6614; 0.7915; and 0.4313.

The values of Zeta or $\eta^2 - r^2$ with their standard errors for the 4 years are respectively 0.0685 ± 0.287; 0.2580 ± 0.0815; 0.1361 ± 0.0489; and 0.0616 ± 0.0271. In every instance, Zeta is 2.3 times or more than its standard error or the equivalent of 3.4 times or more than its probable error. This shows statistical significance and as far as such degree of significance would be acceptable, a non-linear regression is present in the data thus used. For the more exact or closest relationship, the curvilinear relationship existing between such variables as these must be brought out. However, for the approximate and average tendency the linear relationship should serve to show the general concomitant behavior.

Conclusions

Significant relationships between terminal growths in York Imperial apple trees and the individual yields on such growths are shown to be present. Such relationships are of assistance to determine approximate or comparative degrees of yielding potentialities. Interpretation of yield responses can well be made from the terminal

growth responses, and although these growth responses may be of supplemental help for a clearer interpretation of the yield responses, they may be used by themselves for such a purpose very dependably.

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Leaf Weight per Spur Correlated With the Yield of the Baldwin Apple

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IN a study of 157 Baldwin orchards located in the Lake Ontario fruit belt of western New York, need was felt for a measure of vigor which would be accurate for purposes of comparison between orchards, and at the same time practical for use on a large scale. A number of measures were tested. The one which was finally selected as the best for the conditions was the average dry weight of the leaves from 100 spurs. The spurs were gathered in paper bags, placed in cold storage as soon as practical, the leaves clipped off, cutting the petiole at its union with the blade, the leaf blades dried at around 50 degrees C in a herbarium drying room, finished in an electric oven at 100 degrees C; and weighed immediately.

Selection of the spurs required attention. Random samples might have been taken in each orchard, obtaining any spurs from any trees in any positions on the trees. Had the trees in each orchard been uniform, and had conditions of light and other variables been constant, this would have been the ideal method of sampling. Different sections of individual orchards varied greatly in vigor, due to drainage conditions, soil variations, degrees of crowding, and other factors. Samples of spurs were selected to represent the average conditions in each orchard. Ten spurs were taken from each of 10 trees. These 10 trees were selected with regularity (for example, every third tree in the longest diagonal row) when vigor was practically uniform. Where vigor varied widely, a part of the 10 trees proportional to the occurrence of each condition in the orchard was taken. On each tree the most vigorous spurs between 2 and 3 inches long (growth of previous years to union with another twig or branch) exposed to direct sunlight on a southerly exposure and within reach from the ground were selected. In 1932 non-flowering spurs were used; in 1933 flowering spurs from blooming trees. This method of selection was not intended to give an average picture of the condition of the tree, but rather to obtain a composite sample comparable between orchards.

A question may fairly be raised at this point: "Were the samples taken representative of the individual trees selected and of the orchard as a whole?" In answering this question it is necessary to remember that a usual method of testing reliability of sampling methods by standard deviations of the mean is not applicable here. This method is based on random sampling of a more or less uniform population. In the case we are considering, samples were not taken merely at random, and the population is not necessarily uniform (weak or vigorous trees in the same orchard). Under these conditions frequent duplicate samples were taken, duplicates from the same trees, and also from other groups of 10 representative trees. The duplicate samples were treated statistically by Student's method and Fisher's

formula, and in no case is there any significant difference between the duplicate samples.

Example of Check on Method of Sampling Using 50 Orchards with Duplicated Different Trees:

(a) Fisher's Method = .185; odds = 1 to 4.
(b) Student's Method = .222; odds = 5.9 to 1.
(c) Average per cent difference = 7.15 per cent of No. 2 samples.
(d) Maximum per cent difference = 26.4 per cent of lower weight.

Other measures of vigor were also tried. One indication of their relative value is the correlation between individual measures and the average yield in bushels per tree for the 2 year period 1932–33 in which the observations were taken. A table of correlations follows:

TABLE I—Average Yield per Tree Correlated With Measures of Vigor. 109 Baldwin Orchards Over 40 Years Old, Niagara, Orleans, Monroe, and Wayne Counties, N. Y.

Measures of Vigor Used	Number of Orchards Included in Correlation	(r) Correlation Coefficient with Average Yield per Tree 1932–1933	(r^2) Coefficient of Determination
Leaf weight per 100 spurs, June 23–26, 1933	109	.76±.03	.57
Leaf weight per 100 spurs Av. June 26–28, 1932, Sept. 15, 1932, June 23–26, 1933	109	.75±.03	.56
Leaf weight per 100 spurs June 23–26, 1933 (corrected)	109	.90±.01	.81
Leaf weight per 100 spurs May 18–22, 1933	109	.50±.05	.25
Leaf weight per 100 spurs Sept. 15, 1932	109	.67±.04	.45
Size of trees divided by age of trees	109	.36±.06	.13
Average dry weight spurs per year's growth	16	.64±.10	.41
Average age of spurs	16	.65±.10	.42
Dry weight of flowers at center flower open stage. May 18–21, 1933	16	.51±.12	.26
Size of fruits, Sept. 25, 1933	109	.68±.03	.46
Average size largest leaves on terminal growth	40	.68±.05	.46

Of the measures included in the table above leaf weight per one hundred spurs, taken about 1 month to 6 weeks after bloom, seems as good as any other, and considerably better than most as measured by relation to yield of fruit. Two chief factors which tend to weaken its value are differences in severity of pruning and difficulty of obtaining representative samples from the ground in badly crowded orchards. When these factors are arbitrarily corrected by subtracting 10 to 15 grams from the leaf weight in June of the bearing year where pruning is especially severe, and adding 12 grams where severe

crowding makes samples unjustifiably small, and yield is corrected where trees are unusually large or small, the correlation coefficient with yield is very high indeed. This is a rather arbitrary correction, and is presented only as an indication of the relation of the measure to yield when three other variables are corrected.

Figures on terminal growth are being compiled.

The relation between leaf area and leaf weight is also under consideration. That such a relation exists is assumed by Oskamp (1) and others. It varies with varieties, with exposure of the leaves to the sun, age and size of the leaves, and other factors. Dry weight of leaves, when large numbers are being dealt with, may be just as satisfactory or more so that leaf area, in giving a picture of vigor of growth in mature apple trees and possibility of photosynthetic activity. Certainly using leaf weight instead of leaf area saves much time, thus allowing the use of such measures as leaf weight per 100 spurs. This measure has been very satisfactory under the conditions of this study.

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Statistical Analysis of Some Causes of Yield Variations in the Variety Baldwin

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SCOVILLE and LaMont (1) and others have shown by farm management survey studies that the most important factor in determining profit or loss on fruit farms is the yield of fruit obtained. In general, it is known that high yields are associated with well drained soils; adequate supplies of nitrogen, other essential mineral elements, and water; effective spraying; good pollination; and various practices sometimes grouped as "care." How important each of these factors is in determining yields, varies with regions, varieties, seasons, and other factors.

Plot experiments, field trials, and laboratory and greenhouse experiments have provided most of our knowledge of the operation and importance of these factors. Another approach is to ascertain their practical importance under commercial conditions. That approach has been followed in the study here reported, the aim being to find out how important, in average commercial orchards, are soils, spraying, vigorous growth, pruning, and other factors.

To obtain this information a modification of the survey method was used. One hundred and fifty-seven Baldwin orchards, mostly over 40 years old, were selected in the Lake Ontario fruit belt of western New York. On most of these farms, Scoville and LaMont had had survey records for many years, which gave some information concerning yields and practices in the past. In all of them Oskamp, Batjer, and Sweet (2) had conducted rather thorough soil investigations. Instead of only asking the orchardist questions about practices, as surveys often do, counts and measurements were taken in the orchard to determine whether practices were effective. With data obtained previously by surveys and soils work, the further information obtained gives a rather complete picture of conditions in these orchards.

109 Baldwin Orchards Over 40 Years Old, Located in Niagara, Orleans, Monroe and Wayne Counties, N. Y.

Correlations between X_1 (Yield Av. 1932–33); X_2 (Soil index); X_3 (Leaf weight per 100 spurs, June 23–26, 1933); X_4 (Combined worm-scab index. Injury to fruit Sept. 1933); and X_5 (Severity of pruning in last 3 years)

Gross Correlations		Third Order, Partial Correlations		Multiple Correlation
r12 = .62 ± .04	$r^2$12 = .38	r12.345 = .25 ± .06	$4^2$12.345 = .06	R^1.2345 = .87 ± .02
r13 = .76 ± .03	$r^2$13 = .57	r13.245 = .32 ± .06	$4^2$13.245 = .10	R^2.2345 = .75
r14 = −.82 ± .02	$r^2$14 = .67	r14.235 = −.51 ± .05	$r^2$14.235 = .26	
r15 = .56 ± .04	$r^2$15 = .31	r15.234 = .08 ± .06	$r^2$15.234 = .01	

In dealing with the large mass of data obtained, statistical analysis has been employed. In such a group of orchards there is no way to hold all varying factors constant except the one being studied, as is

attempted, often unsuccessfully, in plot experiments. Statistical methods, notably partial correlations and sub-sort tables, purport to accomplish the same purpose. Actually they often do not, due to intercorrelations, etc., in many instances. Care is required in using them, and particularly, caution in interpreting results. With this in mind the correlations are presented in the preceding table.

Interpreting this data, definite conclusions must be avoided. Some inferences may be drawn, however:

(a) A large proportion of the factors associated with yield variations have been measured. While correlation does not necessarily mean causation, in this case it is fair to assume that a large part, probably well over half, of the variation in yield, was due to soil conditions; large vigorous foliage; effectiveness of spraying; and pruning practice.

(b) Of the four factors affecting yield, spraying effectiveness was the most important under the conditions of this study—2 years of heavy scab and codling moth attacks. This is shown in the size of the gross correlations, and particularly in the relative size of the third order partial correlations.

(c) The relative importance of the other three factors is indicated somewhat by the size of gross correlations and third order partials. Probably vigor and abundant leaf area is most important of these three, with soil next and pruning last. The almost complete disappearance of pruning in the third order partial indicates that under these conditions it had little effect on yield independent of vigorous foliage and spraying effectiveness. This does not mean that it was not important, however. Soil is probably more important than it appears since orchards on better soils are sprayed more thoroughly and have better vigor.

(d) The relative importance of these factors is perhaps given best by the relative sizes of the squares of the gross correlations. Where two or more of the independent variables are interrelated, as are X_2 and X_3, X_3 and X_5, X_4 and X_5, etc. here, partial correlations minimize the importance of the interrelated factors. In this case R^2 1.2345 is almost twice as large as the total of the third order partial squares.

(e) A part, probably around one-fourth, of the variation in yield has not been accounted for. Part of this may be due to weather differences in the four counties. For instance, Wayne County suffered badly from drought this past season, and yet early conditions were such that scab at delayed dormant and pink stages was worse than in the other counties. Crowding of trees may be a factor, and others not taken into account. Probably a part of the unaccounted for variability is due to failure of the measures used to represent adequately the conditions they were intended to gauge.

Some other factors which might affect yield were investigated, and particularly other measures to represent the main factors discussed. It was thought that pollination might affect yield, even in the variety Baldwin. A correlation of $-.27 \pm .09$ was found between yield and average number of seeds. If this indicates anything it

coincides with the findings of MacDaniels and Heinicke (3) that more seeds are required to stick young fruits in neglected orchards and the recent work of Brittain (4) in Canada, and others, showing that Baldwin sets well with its own pollen under most conditions. Distance from Lake Ontario, all orchards being within 10 miles, proved to have no effect on yield, the correlation being — .09 $\pm$ .06. All orchards blossomed adequately either in 1932 or 1933, there being no significant correlation between average per cent bloom for the 2 years and yield of fruit. Size of fruit gave a high positive correlation .68$\pm$.03. This factor is closely related to vigor and abundance of foliage and to soil conditions which explains its omission from the multiple correlation given above.

The soil index used is composed of data on color and texture of the soils, depth of rooting of mature trees, and topographic features relating to surface drainage, kindly furnished by Professor Joseph Oskamp of the Cornell Station, plus a measure of moisture supply during the dry months of summer.

Many questions are not answered, nor is the problem of variations in yield even in one variety under one set of conditions. Some indication of the relative importance of different factors under these conditions may have been given. Subsort tables, which time prevents presenting here, give relationships between yield and independent variables in a different form more easily understood by practical orchardists than correlations.

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Effect of Defloration on Spur Leaf Area in the McIntosh Apple

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THERE is abundant evidence to indicate the importance of leaves in the fruiting of a plant. There is also considerable evidence to suggest a correlation between blossom development and leaf area. Chandler and Heinicke (1) reported a tendency for grapevines to have a relatively greater leaf area when blossoms were removed. Murneek (2) found the growth of tomato plants greatly increased as a result of blossom removal. More recently several investigators have studied the relation of leaf area to carbohydrate accumulation. Magness and Overley (3) find that an increased number of leaves per apple results in an increase in size of fruit and in fruit bud formation. Aldrich (4) emphasizes the effects of a comparatively large leaf area per fruit on carbohydrate reserves, while Potter and his associates (5), working with Oldenburg apple trees, find the average spur leaf area of trees completely deflorated to be considerably larger than that of spurs from trees on which 50 per cent of the spurs were allowed to blossom.

In the light of these investigations it appears that the blossom draws heavily on the carbohydrate reserves, which process in turn has a dwarfing effect on the spur leaves, thereby reducing the amount of photosynthetic activity. It is reasonable therefore, to assume that a relatively large leaf area early in the season is essential if the apple tree is to bear a maximum crop. Among the factors which apparently exert a depressing effect on early leaf area are lack of nitrogen, spray injury, and excessive bloom.

Method of Procedure

In the present investigation the writer has endeavored to measure with a reasonable degree of accuracy, the reduction in spur leaf area resulting from blossom development. The McIntosh variety, usually considered an annual bearer, was chosen for the test. On two fairly vigorous 12-year-old trees, branches were selected as follows: On the north side of the tree, two branches, each about 2 inches in diameter and similarly located as regards exposure to light, were selected, one to be deflorated later and the other to serve as a check. A similar pair of branches was selected on the south side of the tree. This selection was repeated on tree number 2. Both trees were due to bloom heavily.

As soon as the blossom clusters had opened sufficiently, the blossom buds were removed. Blossom buds were removed on May 14, which was 11 days before the trees were in full bloom. It was necessary to return on two or three subsequent days to remove an occasional blossom bud not sufficiently developed at the start.

The first comparison of spur leaf areas was made from spurs collected during full bloom (May 25). About 30 spurs were collected

from each of the eight branches. From the check branches only blossoming spurs were removed and from the others only those spurs which had been deflorated. No vegetative spurs were included. All of the leaves were then carefully removed and pressed for future measurement.

The second collection was taken on June 8, 2 weeks after the first collection. Approximately the same number of spurs were removed from both the deflorated branches and from check branches, thus equalizing any pruning effects resulting from spur removal.

On July 4, the third collection of spurs was made as before. Incidentally, the spur collection from check branches was confined to those bearing one apple. This was done to eliminate spurs of more than average vigor. In this lot, however, the leaves were not measured. Instead, they were clipped off and placed in paper bags for subsequent weighing.

Leaf areas were measured by means of a planimeter, the leaves being placed in a semi-circle with edges barely touching. A plate of glass was then laid over the leaves and a drop of melted paraffin placed upon the glass as an anchorage for the stationary leg of the planimeter, the glass being so placed as to bring the paraffin near the center of the circle of which the row of leaves formed an arc. In this way it was possible to trace around a number of leaves, generally ranging from 6 to 10, depending on the size. In most cases the area was determined a second time and the average of the two readings taken as the correct value. In general the two readings checked to within 0.2 square inch. The leaves were also weighed to obtain an area-weight ratio for later determinations. The average ratio for spurs collected May 25 was 21.2 and that of the second spur collection 21.8.

Average spur leaf areas were determined for each of the three spur collections, May 25, June 8, and July 4. From these values were deducted the average spur leaf areas at time of defloration. This was determined from two fairly representative spurs taken from each branch at that time. The difference between these two average values represents the increase in spur leaf area between the time of defloration and the time when spurs were collected.

Results

Table I presents the essential items. In the first spur collection the average increase in spur leaf area of deflorated spurs over check spurs varies from 41 per cent to 54 per cent. Thus it appears that the removal of blossoms resulted in a leaf area on those spurs about half again as great as on the check spurs.

In the second spur collection an increase in leaf area of deflorated spurs over check spurs occurs in all but the first case. Since this is the only exception in the 12 comparisons, it is quite obvious that the discrepancy is due to an error of some sort and does not represent an actual decrease. The other three deflorated branches show a substantial increase in leaf area over check branches.

TABLE I—EFFECT OF DEFLORATION ON SPUR LEAF AREA IN THE MCINTOSH APPLE (SPURS DEFLORATED MAY 14, 1932)

Branch	Number Spurs Sampled	Leaf Area per Spur (Sq. In.)	Increase After Defloration (Sq. In.)	Average Increase (Per cent)
		Sampling May 25		
Tree 1				
A1 (deflorated)....	30	4.07	1.95	44
A2 (not deflorated)	31	3.62	1.35	—
B1 (deflorated)	30	3.74	1.97	41
B2 (not deflorated)	31	3.2	1.39	—
Tree 2				
C1 (deflorated)	30	4.65	2.13	52
C2 (not deflorated)	31	3.79	1.4	—
D1 (deflorated)	30	4.66	1.65	54
D2 (not deflorated)	31	4.29	1.07	—
		Sampling June 8		
Tree 1				
A1 (deflorated)	24	9.23	7.11	—3.3
A2 (not deflorated)	25	9.62	7.35	—
B1 (deflorated)	23	9.55	7.78	18
B2 (not deflorated)	27	8.39	6.58	—
Tree 2				
C1 (deflorated)	22	9.63	7.11	55
C2 (not deflorated)	25	6.98	4.59	—
D1 (deflorated)	25	11.27	8.26	28
De (not deflorated)	26	9.66	6.44	—

	Number Spurs Sampled	Weight* Leaves per Spur (Gms.)			Per cent Increase		
		Primary	Secondary	Total	Primary	Secondary	Total
			Sampling July 4				
Tree 1							
A1 (deflorated)	52	.091	.387	.478	71	13.8	27
A2 (not deflorated)	50	.038	.34	.378	—	—	—
B1 (deflorated)	51	.143	.409	.552	130	15.2	32
B2 (not deflorated)	51	.062	.355	.417	—	—	—
Tree 2							
C1 (deflorated)	50	.078	.312	.39	40	36.2	36
C2 (not deflorated)	51	.056	.229	.285	—	—	—
D1 (deflorated)	51	.094	.376	.47	104	12.9	24
D2 (not deflorated)	39	.046	.333	.379	—	—	—

*Having established the fact that the dry weight of leaves represents a fairly accurate measure of relative areas, this lot of leaves was carefully weighed instead of being measured.

Likewise in the spurs collected July 4 increases varying from 24 to 36 per cent are to be noted in the deflorated spurs. When the leaves were removed from the spurs, the primary leaves were kept separate from the secondary leaves. This was done to determine in which the greater increase took place. The data indicates an increase in primary leaves ranging from 40 to 130 per cent, while the secondary leaves increased from about 13 to 36 per cent.

Discussion

The average increase in leaf area as a result of defloration in the McIntosh apple is found to be about 35 per cent. A smaller increase at the end of the 6 weeks' period under consideration suggests the approach of a balance later in the season, as found by Potter (5). These results appear to be rather significant from the standpoint of fruit bud formation. If a tree blooms very heavily, it fails to store a sufficiently high carbohydrate reserve to insure a set of fruit buds for the next year. This seems to be a characteristic of the biennial bearing tree. On the other hand, if a smaller proportion of the spurs set fruit in any one year, the average spur leaf area is greater and a greater carbohydrate reserve is built up. Thus the tree is enabled to set fruit buds for the following year at the same time it is developing the present season's crop. The work of Bailey (6) indicates the necessity of removing about 90 per cent of apple blossoms to insure development of fruit buds for the following season. However, no practical means of bringing about the desired reduction has thus far been suggested.

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Time During Which Fruit-Bud Formation in Apples May be Influenced in the Shenandoah-Cumberland Fruit Districts

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NUMEROUS investigators have studied the buds of apples to determine by microscopic examination when the first visible evidence of the flower primordia occurs. The results of these investigations have shown that in the middle latitudes of the United States the early stages of flower formation can usually be detected in occasional buds in late June, and buds showing early stages can be found throughout July and into August. Such investigations have given a fairly clear picture of the time the visible evidence of flower formation occurs, but have not shown just when the influences are effective which determine the differentiation of the bud.

During the growing seasons of 1931 and 1932, series of experiments were inaugurated on a number of varieties to determine how late in the growing season buds of the apple could be influenced to form flower parts. Previous experiments had shown that if branches are ringed early in the growing season, leaving a large amount of foliage in relation to the amount of fruit on such branches, abundant fruit-bud formation for the following season would occur. Where approximately 100 good leaves per fruit had been left on such branches and where the ringing was done prior to June 15, the percentage of fruit-bud formation was very high.

Consequently as soon as the fruit set could be determined, typical branches on several varieties were selected for experimental work. These branches carried approximately equal amounts of fruit in relation to foliage prior to adjustment and ringing. Selection was made at the beginning of the season in order to have them as uniform as possible for the successive dates of treatment. Branches were adjusted by fruit removal to leave 100 good leaves per fruit, and rings of bark were removed to prevent the translocation of synthesized food materials from these limbs. Six to eight branches were treated in each variety at each date. Series of branches were treated at successive dates beginning in late May or early June and continuing at intervals of approximately 15 days until September.

Similar branches were selected and tagged as check branches for the treatment. These check branches were not ringed, neither was there any adjustment of foliage and fruit, and they therefore represent approximately what would have been expected in the treated branches had no treatments been given.

In the spring following, detailed records were made on these branches of the total number of growing points and the percentage of these points which formed fruit-buds. Any bud which started into growth the following spring, whether a spur, a lateral bud on the pre-

vious season's growth, or a terminal, was considered a growing point and a record made as to whether or not it developed flower parts.

So long as fruit-bud formation on the ringed branches averaged appreciably above that on the check branches, the treatment is believed

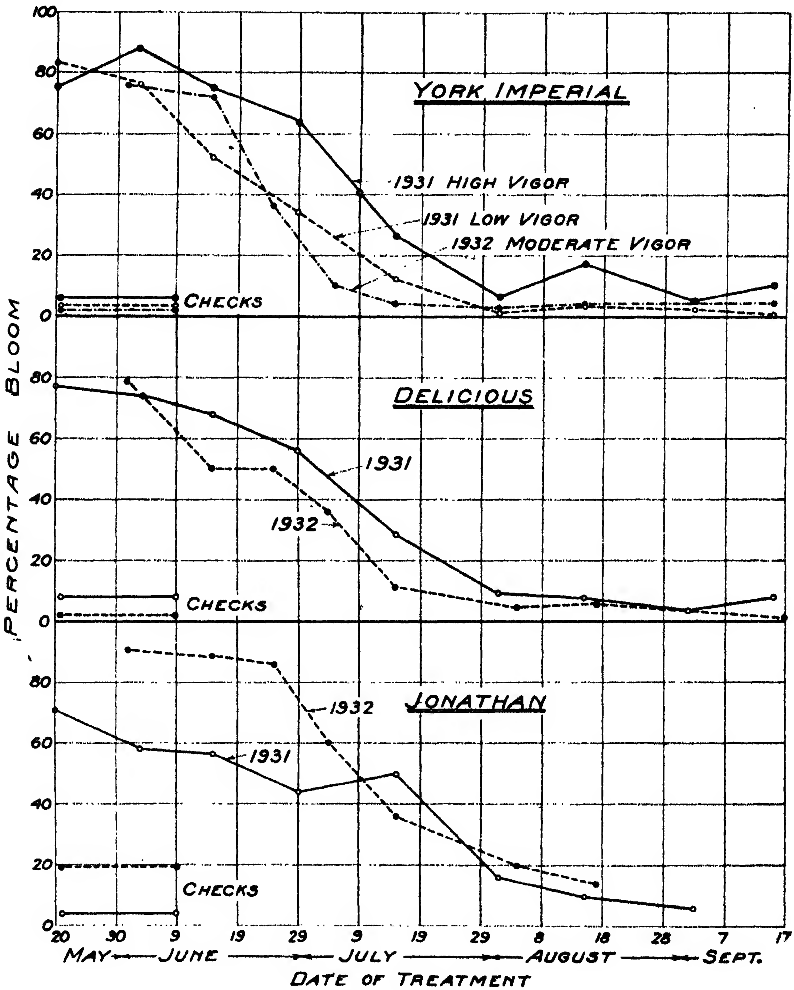

FIG. 1. Percentage bloom in York Imperial, Delicious, and Jonathan apples following ringing and partial fruit removal at various dates during the previous summer.

responsible for the difference. Probable errors of the averages have been calculated for the individual readings of the different varieties and in most cases have been not greater than ±2 to 3 per cent, with a maximum probable error of 8 per cent on one reading. The data for each date on each variety are based on the performance of at least

six individual limbs and in most cases are based on the performance of between 400 and 1,000 growing points. Behavior of the check limbs is based on the performance of between 1,000 and 2,000 growing points in 1931–32 and approximately 1,000 growing points for each variety in 1933.

Curves showing the percentage of the total number of growing points which produced flower buds for the different varieties during the two seasons are shown graphically in Figs. 1 and 2. The average amounts of fruit-bud formation on the check branches are also indicated.

From the data in Figs. 1 and 2 it is apparent that the treatments as outlined, namely, reducing the fruit crop to leave approximately 100 leaves per fruit and ringing the branch, if applied in early June, resulted generally in more than 80 per cent of all growing points forming fruit-buds. Following treatment on June 15, there was in most varieties a slight reduction in the percentage of fruit-bud formation as compared with the June 1 treatment, although the average fruit-bud formation on the June 15 branches was above 70 per cent in most of the tests.

There was a sharp drop in the percentage of the buds which were influenced to differentiate blossoms when the treatment was delayed until the end of June, or approximately 60 to 65 days after full bloom. Also, there was considerable variation in the behavior of the several varieties, in the behavior of the same variety in the two seasons, and on trees in different conditions of vigor. This is further brought out by the data in Table I in which the intervals between full bloom and the last date at which fruit-bud formation can be influenced are shown. All varieties tested both seasons could be influenced slightly longer in 1931 than in 1932. The blooming date was almost exactly the same in the two years, and both seasons were fairly dry in July though the drought was more severe in 1932 than in 1931.

With York Imperial in 1931 and Oldenburg in 1932, a comparison of trees in moderately high and in low vigor was made. In each case, buds on trees in high vigor responded later than on trees in low vigor. Similarly with Delicious trees under irrigation at Wenatchee, Wash., as reported by Harley et al, (1) a considerable number of buds could be influenced to form flower parts more than 90 days after full bloom while the Delicious in the present tests could not be influenced at all later than 81 days after full bloom. It seems probable that the much greater vigor of the trees at Wenatchee is primarily responsible for this difference. Under conditions of high vigor, it seems probable that a larger proportion of the buds or growing points remain in a meristematic condition until midsummer or later, and therefore the development of the buds may be influenced until a slightly later date. These data are indicative of the value of maintaining a vigorous growth condition in trees if steps are being taken to attempt to influence fruit-bud formation by fruit thinning or similar practices.

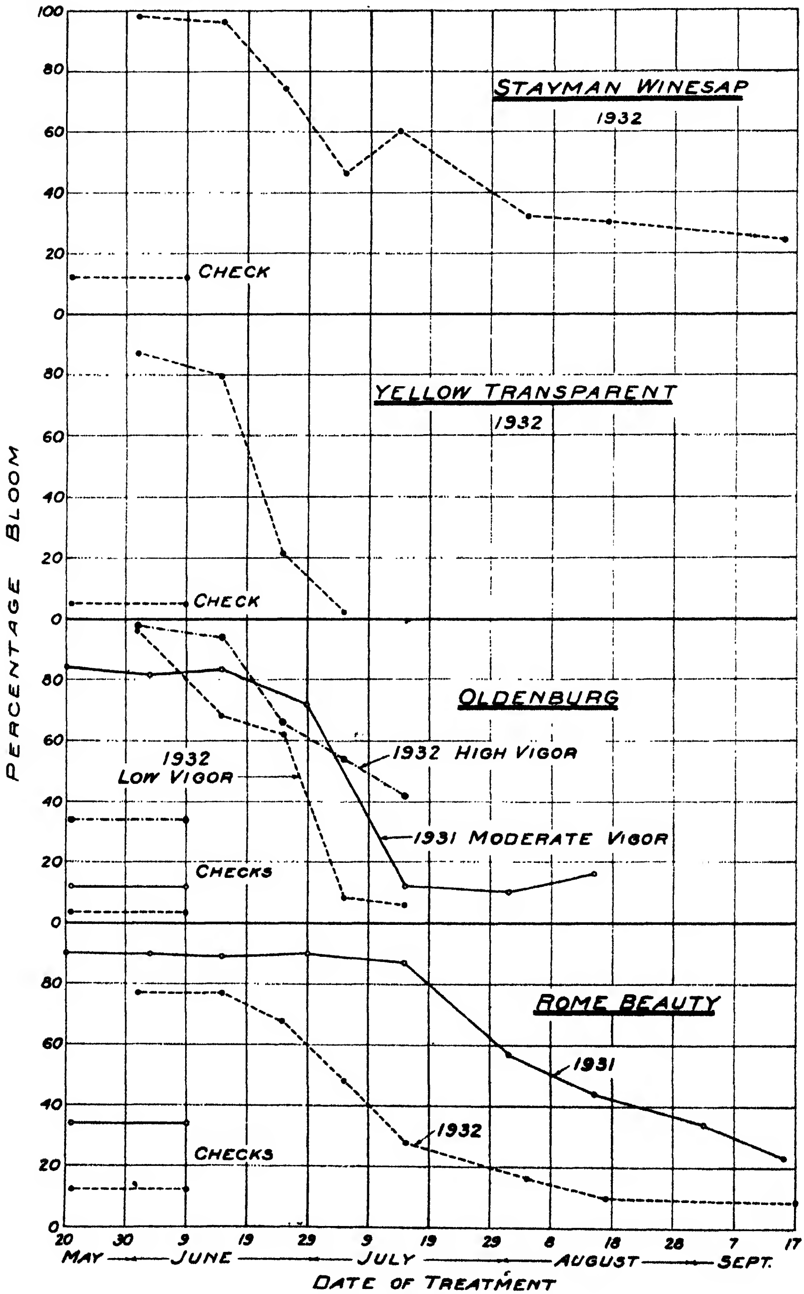

FIG. 2. Percentage bloom in Stayman Winesap, Yellow Transparent, Oldenburg, and Rome Beauty apples following ringing and partial fruit removal during the previous summer.

TABLE I—INTERVAL AFTER FULL BLOOM (FIRST PETAL FALL) AFTER WHICH FRUIT-BUD FORMATION COULD NOT BE INFLUENCED BY RINGING AND FRUIT REMOVAL, AND INTERVAL AFTER WHICH NOT MORE THAN 25 PER CENT OF BUDS COULD BE INFLUENCED (AS COMPARED TO RESPONSE ON CHECK BRANCHES)

Variety and Year of Treatment	Days Until Only 25 Per cent Responsive	Days Until Responsiveness Ceases
York Imperial		
1931—high vigor	62	74
1931—low vigor	51	68
1932—moderate vigor	54	61
Delicious—1931	71	81
1932	68	75
Delicious, Wenatchee, Wash.*	90	110
Jonathan—1931	84	100
1932	71	90
Rome Beauty—1931	83	99
1932	65	89
Oldenburg—		
1931	73	80
1932—low vigor	62	66
1932—high vigor	63	76
Yellow Transparent—1932	55	63
Stayman Winesap—1932	85	105

*Data by Harley, Masure, and Magness. Proc. Amer. Soc. Hort. Sci. 1932.

The different responses of varieties is also of interest. Of the varieties studied, the period during which Yellow Transparent, York Imperial, Oldenburg, and Delicious could be influenced following full bloom was relatively short, while Jonathan, Stayman Winesap, and Rome Beauty could be influenced during a distinctly longer period. This response is in accord with the general behavior of these varieties relative to the maintenance of regular bearing, the latter varieties being much easier to maintain in regular production.

The fact that even on ringed branches with abundant foliage, fruit-bud formation can be influenced for periods of not more than 60 to 90 days following blossoming, and that most of the buds can be influenced for only about 40 to 50 days (June 15 in these tests), indicates that any response from such practices as fruit thinning of normal trees can be expected only if the thinning is done very early. Results of thinning tests conducted to date on trees in condition similar to those used in the present work indicate that little response can be expected even from heavy thinning if it is not done within about 30 days of time of full bloom. Abundant fruit-bud formation in York Imperial, even on heavily set branches, was obtained by Aldrich and Fletcher (2) from thinning to 100 leaves per fruit on May 18 (8 days after full bloom), and fairly good fruit-bud forma-

tion from thinning on June 4 (25 days after full bloom). Later thinning has not been effective on very heavily set trees.

It is to be expected that any treatment applied to the tree as a whole, with the possibility of free translocation of nutrient materials, will be less effective than on ringed branches. Treatments, to be effective in determining fruit-bud formation, apparently must be applied sufficiently early to modify nutritional conditions within the buds in late June, or within 50 to 60 days after full bloom, under Middle Atlantic conditions.

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Carbohydrate Storage in Apple Trees[1]

By A. E. MURNEEK, *University of Missouri, Columbia, Mo.*

THE growth and development of an apple tree, like all perennial plants, is determined largely by the food reserves, primarily carbohydrates, that accumulate during the growing season and are made available in the spring.

As a continuation and extension of our studies of the autumnal migration of carbohydrates from apple leaves (3), we have investigated the movement and quantitative distribution of these substances in the structural parts of the tree. More specifically, the object of this study was to learn in what quantities and where the various carbohydrates are stored at the end of the growing season.

Normally developed and bearing 18-year-old trees of the varieties Grimes, Jonathan, and Delicious, served as material for this purpose. They were felled at appropriates times, from October to December, and separated at once into the following parts: leaves; spurs; 1-, 2-, 3-, 4 to 6-, 7 to 10-, 11 to 18-year-old wood, and the main stem. At the same time the roots were excavated and cut into four portions: the stump and 18 to 14-, 13 to 7-, and 6 to 1-year-old roots, the age being determined by counting of growth rings. All tissues were prepared for chemical analysis by drying in the usual way. Determinations were made of fresh and dry weights, total sugars, starch, hemicellulose, and total carbohydrates. The results are presented in Tables I and II.

The data show a continuation of translocation of carbohydrates from the peripheral regions to the larger branches and roots, which, as we know, is initiated in midsummer. There is an evident hydrolysis of starch and probably hemicellulose (2, 4) to sugars. This, too, is a well known winter phenomenon in deciduous trees. But the most striking feature of these records is the unusually high starch and sugar content of the roots. Apparently the underground parts of the apple serve as storage organs for carbohydrates, primarily starch. In this respect, then, the apple tree behaves like a more or less typical biennial plant. Table II shows that although the roots weighed only a third as much as the top, the total quantity of starch present was almost as high as in the aerial portion of the tree, despite the presence of proportionately larger quantities of hemicellulose and sugars.

The trees used for our investigation bore a normal crop of fruit. They were, therefore, in what may be considered the "on" year. It would be of great interest to know the proportional accumulation of starch and other carbohydrates in the roots of biennially bearing trees in an "off" year. Furthermore, it would be even more desirable to learn where and in what relative quantities the more plastic carbohydrates are removed in the spring and utilized for the develop-

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TABLE I—AUTUMNAL CHANGES IN CARBOHYDRATE CONTENT OF BRANCHES AND ROOTS OF THE APPLE TREE. AVERAGE OF THREE VARIETIES. (IN PERCENTAGES ON DRY WEIGHT BASIS)

Date	Age of Branches (Years)					Size of Roots		
	1	2	3	4–6	7–10	16–17	Large	Small
October 12								
Sugars, total	4.35	4.01	2.92	—	—	—	—	—
Starch	5.47	5.39	4.16	—	—	—	—	—
Hemicellulose	25.59	22.35	22.34	—	—	—	—	—
Carbohydrates, total	35.41	31.75	29.42	—	—	—	—	—
October 27								
Sugars, total	4.63	3.64	3.08	—	—	—	—	—
Starch	7.53	6.98	6.00	—	—	—	—	—
Hemicellulose	23.20	25.25	26.18	—	—	—	—	—
Carbohydrates, total	35.36	35.87	35.26	—	—	—	—	—
November 10								
Sugars, total	4.68	4.08	3.36	2.81	2.89	2.38	3.00	4.94
Starch	6.49	5.64	5.74	3.06	5.01	4.06	12.90	16.09
Hemicellulose	22.56	21.19	23.00	21.41	22.56	23.16	23.49	23.48
Carbohydrates, total	33.73	30.91	32.10	27.28	30.46	29.60	39.39	44.51
November 26								
Sugars, total	5.23	4.72	4.08	—	—	—	—	—
Starch	4.85	4.71	4.10	—	—	—	—	—
Hemicellulose	24.22	23.99	26.92	—	—	—	—	—
Carbohydrates, total	34.30	33.42	35.10	—	—	—	—	—
December 28								
Sugars, total	6.62	5.73	6.84	5.44	5.31	3.70	3.88	6.57
Starch	3.78	2.35	2.40	2.46	3.19	3.84	11.77	13.90
Hemicellulose	22.21	23.06	25.39	22.89	22.59	23.00	21.67	20.13
Carbohydrates, total	32.61	31.14	34.63	30.79	31.09	30.54	37.32	40.60

ment of shoots, leaves and flowers, how much may be present when fruit buds are formed, and what amounts are necessary for the production of an average fruit crop.

It has been shown (5) that coincident with growth and development in the spring, starch disappears progressively from the apple tree, beginning with the younger twigs and extending to the lower portions of the branches. The apple fruit, of course, has a high carbohydrate content, most of which, however, seems to be supplied directly through current synthetic activity of the leaves.

The relative concentration of starch and other food reserves in the limbs and roots of the apple tree have a bearing on pruning practices. One would expect that trees having ample carbohydrate reserves, coupled with proper nitrogen supply, would be able to regenerate shoots more readily and extensively than those lacking it. To preserve this stored food, trees should be pruned only after most of the carbohydrates have been moved to the main limbs and roots. The relationship of pruning to starch storage has received already a pre-

TABLE II—QUANTITATVIE DISTRIBUTION OF CARBOHYDRATES IN THE APPLE TREE. VARIETY JONATHAN, OCTOBER, 1928

Material	Fresh Weight (Pounds)	Dry Weight (Pounds)	Sugars (Pounds)	Starch (Pounds)	Hemi-cellulose (Pounds)	Total Carbo-hydrates (Pounds)
Leaves........	51.5	28.72	2.13	.57	4.58	7.28
Spurs.........	10.6	6.63	.32	.49	1.84	2.67
Branches, 1 yr.	9.6	6.10	.27	.47	1.41	2.15
Branches, 2 yr.	12.0	7.65	.37	.45	1.32	2.14
Branches, 3 yr.	11.6	7.48	.28	.46	1.84	2.57
Branches, 4-6 yr..........	76.8	44.20	1.71	1.91	10.55	14.17
Branches, 7-10 yr..........	185.6	127.10	4.33	5.25	29.53	39.10
Branches, 11-18 yr.......	267.1	160.60	4.21	5.41	38.45	48.02
Main stem....	98.1	60.61	1.70	4.54	14.24	20.23
Total, above ground....	722.9	449.09	15.32	19.55	103.76	138.33
Root, stump...	84.5	48.19	1.32	5.30	11.08	17.84
Roots, 18-14 yr.	103.3	62.19	1.83	7.06	15.35	24.24
Roots, 13-7 yr.	72.0	36.00	1.83	4.42	9.50	15.77
Roots, 6-1 yr.	12.7	5.72	27	.66	1.43	2.40
Total, below ground....	272.5	152.10	5.25	17.44	37.36	60.25
Total for tree..	995.4	601.19	20.57	36.99	141.12	198.58

liminary study (1). It may be anticipated that further inquiry into this phase of metabolism of the apple may give fruitful results.

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Carbon Dioxide Assimilation of Baldwin Leaves on Different Sides of the Tree

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It has been generally accepted that light, temperature, and the CO_2 content of the air have a marked positive correlation with the photosynthetic activity of leaves. Assuming this to be true, and in the absence of any inhibiting factors, one would expect leaves on the north side of a tree to be much less active than those on the south side because of the higher temperature in sunlight and because of the higher light intensity. To test this hypothesis, a series of experiments were conducted in the orchards of Cornell University, Ithaca, N. Y., during the summer of 1933.

The apparatus recently described by Heinicke and Hoffman (1) for measuring CO_2 assimilation under natural conditions was suitable for this study since it could be readily carried from tree to tree and allowed the testing of several leaves at the same time. A machine containing ten absorption towers was used. Thus eight leaves could be tested simultaneously and two towers left drawing on the free atmosphere to check the amount of CO_2 in the air.

The first series was run on Baldwin tree AJ 2, beginning June 12. Leaves on vigorous spurs were selected and exposed to direct sunlight, as indicated in Table I.

TABLE I—Location and Amount of Direct Light to Eight Leaves

Leaf No.	Side of Tree	Exposure to Direct Sunlight
1	Southeast	Sunrise to 5 p.m.
2	Southeast	Sunrise to 5 p.m.
3	Southeast	Sunrise to 12 p.m.
4	Southeast	Sunrise to 4 p.m.
5	West	Sun from 12 m. to sunset
6	West	Sun from 12 m. to sunset
7	Northwest	Sun from 5 p.m. to sunset
8	Northwest	Sun from 5 p.m. to sunset

It is apparent that during a run from 8 a. m. to noon or 1 p. m. the leaves on the east side of the tree would have the advantage of greater light intensity on a clear day. Runs were made for 6 consecutive days. The CO_2 assimilation is given in Table II.

The data are in line with expectations. The leaves on the east side received more light during the morning hours and used more CO_2. The objection could very properly be made that during the afternoon the relationship as to light would be reversed and that, therefore, the total assimilation per day would be equal. Runs conducted from sunrise to sunset were needed to answer this question.

Beginning June 19, the leaves described above were run almost continuously from sunrise to sunset. The day was divided into three

TABLE II—CARBON DIOXIDE ASSIMILATION OF LEAVES (IN MGRS. CO_2 PER 100 CM^2 PER HOUR)

Date June	Time	S E Side				W and N W Sides				Sky
		1	2	3	4	5	6	7	8	
12	9–2	14.3	16.4	16.1	8.9	15.8	14.0	9.0	11.6	Intermittent clouds
13	8–1	11.6	11.7	14.5	14.4	14.2	10.8	9.7	9.0	Intermittent clouds
14	8–12	8.3	7.2	9.6	10.0	11.7	1.0	7.0	7.0	Cloudy
15	8–1	13.3	13.8	13.7	14.5	8.9	6.2	11.0	6.0	Bright, clear scattered clouds
16	8–1	13.3	14.3	10.2	13.7	12.0	10.1	11.7	12.3	Cloudy to sunny
17	8–1	18.1	14.2	12.2	16.5	11.4	9.5	11.0*	8.9	Intermittent clouds to bright
Average. .		13.2	12.9	12.7	13.0	12.3	8.6	9.9	9.1	
		Average East = 13.0				Average West = 10.0				

*Estimate.

TABLE III—CARBON DIOXIDE ASSIMILATION OF LEAVES AT DIFFERENT TIMES OF DAY AND ON DIFFERENT SIDES OF THE TREE (IN MGRS. CO_2 PER 100 CM^2 PER HOUR)

Date June	Time	S E Side				N W Side			
		1	2	3	4	5	6	7	8
19	4–9	13.6	11.2	9.5	8.1	2.6	3.8	6.1	5.9
19	9:15 2:45	18.2	17.3	18.7	15.8	12.1	13.3	11.1	12.1
20	4:37 9:07	13.2	11.7	9.6	11.3	5.1	6.0	6.9	6.9
20	2:30 7:30	4.7	8.9	5.7	9.9	9.9	10.8	9.1	12.5
21	9:15 2:15	13.0	9.7	14.8	15.8	11.3	7.8	7.3	6.6
21	2:25 6:30	8.3	5.6	5.3	7.4	7.0	9.2	8.6	10.6
22	4:35 9:05	5.8	5.0	3.7	6.6	3.8	3.8	X	3.0
22	9:14 2:14	8.5	14.5	16.8	18.2	12.7	10.2	22.8	8.0
23	5–9	14.7	10.9	9.0	10.4	2.7	1.5	3.5	4.7
23	2:06 6:56	7.6	6.5	6.1	9.7	12.0	11.6	10.4	14.2
24	9:11 2:11	9.9	10.7	12.6	12.7	7.6	9.2	8.1	7.8
24	2:20 6:50	6.6	4.4	5.8	9.1	7.3	9.8	7.5	7.9
26	5:05 9:05	X	8.6	6.6	8.5	7.9	7.9	6.5	6.3
26	9:15 2:15	X	13.2	13.5	17.5	14.4	13.7	10.3	11.2

periods: just before sunrise to about 9 a. m., 9 a. m. to about 2:30 p. m., and 2:30 p. m. to about 7 p. m. This series covered about 14 hours and included all of the day when photosynthesis was active. Two of the three runs were made each day for 7 days. The results are given in Table III.

Light conditions were favorable for photosynthesis during the full week except during a hail storm at 6:30 p. m. on June 21. It is clear that the leaves on the east side assimilate about twice as much as those on the west side during the early morning run. There is less difference during the mid-day run and a tendency for the leaves on the west side to do a little better during the later afternoon run. To simplify the data, the averages for these three periods are given in Table IV.

TABLE IV—AVERAGE CO_2 ASSIMILATION AT DIFFERENT TIMES OF DAY BY LEAVES (MGRS. CO_2 PER 100 CM^2 PER HOUR)

Leaf Number	Side	Period 1 (4:30–9:00)	Period 2 (9:00–2:30)	Period 3 (2:30–7:00)
1	SE	11.8	12.4	6.8
2	SE	8.5	13.1	6.4
3	SE	7.7	15.3	5.7
4	SE	9.0	16.0	9.0
Average	East	9.3	14.2	7.0
5	West	4.4	11.6	9.1
6	West	4.6	10.8	10.4
7	NW	5.8	11.9	8.9
8	NW	5.4	9.2	11.3
Average	West	5.1	10.9	9.9

If we assume the usual first run equal to 4½ hours, the second to 5½ hours and the last to 4½ hours and multiply the average assimilation by these figures, the average daily CO_2 assimilation per 100 cm^2 leaf surface on the east side is 151.5 mgrs. and on the west 127.6 mgrs. This increase is less than the 30 per cent reported in Table II but is appreciable (19 per cent).

Leaves on the same side of the tree may receive very different amounts of light due to the angle of exposure, the shade of other leaves, etc. A Weston Illuminometer, measuring light intensity very accurately in foot candles, was available. The relative amount of light striking leaves used in this test may be of interest (Table V). The light intensity striking the leaves was determined by laying the meter target on the upper surface of the leaf and parallel with the blade.

A striking variation in the relative amount of light reaching the different leaves is noted. It is apparent, however, that the leaves on the east side have higher intensities on the average.

The water supply to the leaf tissues is less apt to be limiting on account of incipient wilting in the morning than in the afternoon, and stomates are probably open for a longer period in the forenoon. Thus

TABLE V—LIGHT STRIKING LEAVES AT DIFFERENT TIMES OF DAY

(Weather clear except for slight haze and intermittent clouds). (June 19 for 5:00 A.M. to 2:15 P.M. Readings Inclusive. June 20 for 4:00 and 7:30 P. M. readings)

Leaf Number	Time							
	5:00	6:30	8:15	9:00	12:00	2:15	4:00	7:30
1	380	5100	1200	6000	3000	1800	4000	38
2	240	2200	2000	7500	6000	3200	840	60
3	200	500	750	6000	2000	1000	1000	17
4	200	400	1400	6000	5000	3200	1400	50
5	190	400	1500	1100	3000	3400	4400	84
6	195	380	1800	900	3000	4000	6600	94
7	19	500	1300	1400	1400	2000	860	53
8	200	410	1200	875	1200	2000	3400	66

leaves exposed to the sun during the morning are in a position from the standpoint of water supply, CO_2 supply, and also temperature, to take fullest advantage of the available light. The importance of the morning period for photosynthesis with apple, as indicated by the above data, is directly opposed to the results secured by Schanderl (2) working with grapes. These results were secured using leaves on vigorous spurs. It may be that leaves on terminal shoots behave differently. Further investigation along this line is planned.

ACKNOWLEDGMENT

Dr. A. J. Heinicke suggested this study and has given valuable aid in all phases of the work.

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Control of Biennial Bearing in Apples

By A. C. McCormick, *Husum, Wash.*

THE biennial bearing habit is well established in most of the Yellow Newtown and Ortley orchards of the Pacific Northwest. Enormous crops of comparatively small sized fruit are produced during the on-year but little or no fruit during the off-year. After producing these heavy crops the trees show evidence of near exhaustion. Many attempts have been made to modify this habit through some particular system of pruning or thinning and by the use of fertilizers. Such attempted corrections have proved of little or no avail.

The experiments described here were carried on in the White Salmon Valley of Washington, which is directly across the Columbia River from the Hood River Valley of Oregon. Thirty trees were used in this experiment consisting of the Yellow Newtown and Ortley varieties and were 20 years of age at the beginning of the test. Previous to this time the trees had been well cared for and nitrogenous fertilizers had been applied annually. Pruning was thorough, the old wood having been removed so that the spurs were mostly on wood from 2 to 6 years of age. Old clustered spurs were regularly pruned out.

Previous to 1926, several fertilizer experiments had been carried on in an effort to correct the biennial bearing habit. These fertilizer experiments revealed the fact that when nitrates were applied to trees, either in the fall or spring, the results were the opposite of those sought. When applied to biennial bearing trees in the on-year, the resulting set of fruit was greater and at the end of the year the trees showed a decided loss of vitality. When applied to annual bearing Yellow Newtown trees nitrogenous fertilizers had the effect of upsetting this habit and converting them into biennial bearing trees.

In 1927 it was decided to make a detailed field study of annual bearing trees in the hope that a clue might be discovered which would lead to an understanding of some of the factors that make for annual or biennial bearing. For this purpose the Anjou pear was selected. First, this variety, under local conditions, was ideal for this study for the reason that it produced heavy crops consistently year after year without loss of vitality. The trees bloomed heavily each year and set the right amount of fruit to produce a full crop. No thinning was necessary. Secondly, these trees were close at hand where observations could be made each day. Studies revealed that the Anjou set from 2 to 3 per cent of its blossoms which matured fruit; another 6 to 8 per cent of blossoms apparently set but dropped during the earlier stages of development, which occurred within 12 to 18 days following full bloom. In one series of bloom and fruit records an average set of 2.8 per cent occurred and was ample for a full crop, all the other blossoms having dropped from natural influences. Attention was then directed to the Yellow Newtown and Ortley varieties of apples.

Plan of the Experiment 1930

The object of the experiment was to determine the effect of reproducing artificially, so far as possible on Yellow Newtown and Ortley, the natural fruiting habit of the annual bearing Anjou pear. The trees selected were as nearly alike as possible and divided into three lots. The following treatment was followed at thinning time:

Lot 1, check trees—no treatment.

Lot 2, at blooming time—two-thirds of blossoms removed by systematically taking off two blossom clusters successively and leaving the third.

Lot 3, at blooming time—three-fourths of the blossoms were removed by systematically taking off three blossom clusters successively and leaving the fourth. (The term pre-thinning will be used to designate this operation.)

Six weeks later, at the regular fruit thinning time all three lots were reduced to the same comparative number of fruits per tree, approximately 3 per cent of individual blossoms. After thinning the ratio was approximately 1 fruiting spur to 6 spurs from which the blossoms and fruit had been removed. Table I indicates that there

TABLE I—Showing Effects of Pre-Thinning of Yellow Newtown and Ortley Apples on the Habit of Blooming, Average Weight of Fruit and Average Yield per Tree

Lot†	Year	Spurs Blooming (Per cent)	Method Pre-thinning	Set Blossom Clusters (Per cent)	Method Thinning	Loss Wt. (Gms)	Av. Wt. Fruit (Gms)	Av. Yield per Tree (Bus.)
Lot 1 check	1930	100	None	57	3 per cent	72	122.4	9.6
Lot 2	1930	100	2/1*	20	3 per cent	23.6	140.4	10.6
Lot 3	1930	100	3/1	15	3 per cent	15.6	152.7	11.4
Lot 1 check	1931	.7	None	84	1 per cluster	28	216.7	.07
Lot 2	1931	36	1/1	35	1 per cluster	7.5	154.2	8.3
Lot 3	1931	56	2/1	23	1 per cluster	7.5	150	8.5
Lot 1 check	1932	100	None	62	3 per cent	69	126.2	9.1
Lot 2	1932	61	2/1	20	1 per cluster	15	142	7.8
Lot 3	1932	42	1/1	28	1 per cluster	16	150	9.3
Lot 1 check	1933	1.1	None	68	1 per cluster	30	198	.12
Lot 2	1933	38	1/1	25	1 per cluster	15.2	144	8.2
Lot 3	1933	46	1/1	24	1 per cluster	15.8	146	9.1

*2/1 indicates that two blossom clusters were removed successively and one was left.

†All treatments received 5 pounds of nitrate of soda.

Explanation: Pre-thinning is a term used to denote the procedure of removing blossom clusters at or about blooming time.

was a prodigious waste of energy by the check trees setting 57 per cent of the spurs and growing the fruit for a period of 6 weeks. This loss was 72 grams per remaining fruit and equivalent to 59 per cent of the final average weight of fruit produced.

The result of pre-thinning in 1930, in addition to increasing the yield, had the effect of setting ample fruit buds for the following year. In 1931 the check trees returned to the characteristic off-year habit, developing only .7 per cent bloom. Lot 2 developed 36 per cent bloom. The individual tree response was quite irregular with a tendency to bloom toward the outer portions of the trees. Lot 3 developed 56.3 per cent bloom. However, some trees were slightly irregular.

In 1932 and 1933 the check trees continued to bear biennially. Since a rigid system of pre-thinning became increasingly difficult after the first year, due to irregularities of blooming, it was decided in 1932 to thin out blossom clusters on lots 2 and 3 as judgment would indicate for individual trees. This method permitted thinning blossom clusters more where abundant and less where sparse. It became apparent, too, that the bearing habits of lots 2 and 3 were almost identical.

Discussion of Results

The immediate result of pre-thinning is to increase the size of fruit. Fruit increased in size from two to four counts, measured by the standard box pack. The most impressive fact revealed in these experiments is the enormous waste manifest at thinning time on lot 1 the on-year. The data presented show that during the years 1930 and 1932 the check trees, from blossoming to thinning time over a period of 6 weeks, carried a load 300 per cent greater, when compared to lot 3, than necessary to produce a full crop.

In order to achieve annual bearing in Yellow Newtown and Ortley trees under local conditions it appears essential that the stored up energy from the previous season must be conserved. It is doubtful if fruit buds are formed alone by the current season's growth activity, except as lateral or terminal buds are formed, but must be assisted by energy stored from the previous season. The outflow of energy, the chief source of which is carbohydrate, during this critical period, of fruit bud formation, must be so regulated and controlled that sufficient energy is present to differentiate fruit buds. At this time either nature or man must interfere to check this lavish use of stored energy by the new, fast developing fruit. It appears that this outflow must be limited to the extent, at least, that such loss is counterbalanced by the newly manufactured materials.

The hope of using nitrate alone to correct the biennial bearing habit in Yellow Newtown and Ortley appears hopeless, since it greatly accelerates the dispersion of carbohydrates at the most critical time of fruit bud formation. By greatly increasing the set of fruit the on-year it defeats the purpose for which intended. However, an abundant supply of nitrogen is of first importance in the conversion of stored energy into the formation of fruit buds. It also promotes general

growth activity, hastens the growth of fruit, and improves the general vigor of the tree. Therefore, a liberal supply of nitrogen is to be greatly desired in conjunction with the control of the outflow of energy through the practice of pre-thinning.

Pre-thinning accomplishes, in reality, that very old principle, the conservation of energy. Practical use is made of this principle when the tree converts the energy present into fruit buds which would otherwise be wasted in the growth of surplus fruit.

Photosynthetic Efficiency of Apple Leaves and the Problem of Biennial Bearing

By A. J. HEINICKE, *Cornell University, Ithaca, N. Y.*

ABSTRACT

This material will be published in bulletin form.

Fruit Thinning and Biennial Bearing in Yellow Newtown Apples

By C. P. Harley, M. P. Masure, and J. R. Magness, *U. S. Department of Agriculture, Washington, D. C.*

FURTHER evidence that leaf function bears a quantitative relation to blossom bud formation in apples has been secured from fruit thinning experiments conducted on biennial bearing Yellow Newtowns near Wenatchee, Wash.

There is a strong tendency for Yellow Newtowns in the Pacific Northwest to bear biennially. This condition may be found in entire trees, or, in some instances, individual main leaders or scaffold branches appear to act as units and function independently from the other portions of the tree, in so far as fruit bud development is concerned. It is not uncommon in trees having, for example, five main leaders, to find two or three in a decidedly "off year" condition while the remaining leaders may be definitely in the "on year." Furthermore, a study of spur performance showed that these leaders, for the most part, had behaved in this manner for the past several years.

Trees of this character offer an excellent opportunity for detailed thinning studies since comparisons between leaders on the same tree are possibly less subject to error than comparisons between whole trees; also, the spur history of these leaders indicated that any movement of food materials from one leader to another which may have taken place was not sufficient to influence blossom bud formation in any measurable degree.

Five of these trees were selected for the fruit thinning experiment. They were large and fairly vigorous as interpreted by terminal growth and character of foliage. The frameworks were of the open or vase type, and consisted of from four to six main leaders.

On June 10, 1932, or 39 days after full bloom, "on year" leaders from each tree were thinned to 70 leaves per apple. Similar leaders were thinned to 50 leaves per apple at this date and the others left untreated. The same treatments were repeated July 9, or 68 days after full bloom. In the spring of 1933 spur performance records were secured from all trees. The percentage of spurs bearing blossoms in 1933 are shown in Table I.

It is quite evident from the data that fruit thinning to a ratio of 70 leaves per apple on June 10 had a pronounced influence on blossom bud formation. Leaders thinned to 50 leaves per fruit on June 10 also showed some effect but the difference between the two treatments is quite marked.

The "Heavy Commercial Thinning," reported in Table I, represents a thinning program far heavier and earlier than is normally practiced in the Wenatchee district. Leaf counts on these trees showed an average of about 50 leaves per apple following thinning. The percentage of spurs and terminals blossoming in 1933 was practically the same in these commercially thinned as in the experimental trees thinned to 50 leaves per apple June 10; although the percentage of blossoms

in 1932 was considerably less on the commercially thinned than on the experimentally thinned leaders.

TABLE I—EFFECT OF FRUIT THINNING ON BLOSSOM BUD FORMATION IN BIENNIAL BEARING YELLOW NEWTOWNS

Leaf-Fruit Ratio, 1932	Thinning Dates 1932	Spurs Blossoming in 1932 (Per cent)	Spurs Blossoming in 1933 (Per cent)	Terminal Buds Blossoming in 1933 (Per cent)
70 leaves per apple.........	June 10	80	35.0	30.4
50 leaves per apple.........	June 10	86	9.7	8.8
Heavy commercial thinning	June 10	73	10.4	13.0
70 leaves per apple.........	July 9	83	4.7	0.0
50 leaves per apple.........	July 9	84	3.2	6.8
"On year"...............	Unthinned	82	1.4	0.0
"Off Year"...............	No fruit	0.2	99.8	92.0

When the thinning was performed as late in the season as July 9, or 68 days after full bloom, the percentage of buds forming blossoms was but slightly greater than those of the "check" or unthinned leaders, regardless of the leaf-to-fruit ratios used.

The percentages of terminal growth blossoms followed somewhat closely the spur percentages, although more variability existed between treatments. A smaller terminal growth population, as compared with the number of spurs, is probably responsible for this variability.

Spurs and terminal buds from the untreated "off year" and "on year" leaders showed typical biennial bearing responses.

These results indicate that blossom bud formation depends primarily on leaf function, and that this may be influenced to a marked degree by fruit thinning. Two factors seem to be very important, however, in its application. *First,* the fruit should be thinned heavily enough to establish the leaf area necessary for fruit bud formation, over and above that required by the developing fruits and extension growth. In the present experiment 70 leaves represented such a thinning program, averaging 1900 square centimeters of leaf surface, or about 4¼ square inches per leaf, exclusive of the small cluster base leaves. Trees in a less vigorous growing condition would probably have smaller leaves which would necessitate increasing the number of leaves per fruit in order to approach the required leaf area. *Second,* the fruit should be thinned early in the season, before differentiation has begun, or before the buds have reached the stage at which they can no longer be influenced by the increased leaf area.

As would be expected, a grower is undoubtedly penalized by excessively large fruits and reduction in the total crop by such drastic thinning. This loss, though, should not extend much beyond the first year, for in this experiment where the fruit was thinned to 70 leaves per apple on June 10, 35 per cent of the spurs formed blossoms the following spring. With these Yellow Newtown trees, which normally set fruit heavily, this percentage of blossoms required a light fruit thinning during the 1933 season. Annual production on these leaders then, should be maintained if proper thinning is exercised.

Pear Fruit Thinning, in Relation to Yield and Size of Fruit for the Same Season[1,2]

By W. W. Aldrich, *U. S. Department of Agriculture, Medford, Ore.*

RECENT study of pear irrigation in the Rogue River Valley, which has shown that fruit growth responses to soil moisture seem correlated with stomatal opening (2) in the leaves, has emphasized the importance of leaves in fruit development. To obtain additional information on the relation of leaves to fruit growth, careful thinning experiments were conducted in 1933 to determine the effect of leaf-fruit ratio on fruit growth.

Materials and Methods

Bearing trees of the Anjou, Bartlett, and Winter Nelis varieties were used. The Anjou trees were a year older but similar to those previously (2) described, and had received a light thinning-out pruning the previous winter. The Bartlett trees, also in clay adobe soil, were smaller than the Anjous and were making rather heavy shoot growth, presumably resulting from extensive blight removal and heavy pruning in 1931 and 1932. The Bartletts had likewise received a light pruning the previous winter. For the Anjous, soil moisture was maintained above 50 per cent of the available capacity. The Bartletts were irrigated four times, and from soil samples in adjoining blocks it seems probable that soil moisture was kept above 50 per cent of the maximum available capacity. The Winter Nelis had received moderately heavy annual pruning, and were on well-drained residual soil, (classified as Sites silty clay loam) at the Southern Oregon Experiment Station. The four irrigations applied to the Winter Nelis undoubtedly kept the soil moisture highly available.

For the Anjou trees, the total number of fruits on each major limb was counted, and the total number of leaves estimated by counting all the leaf clusters (each shoot considered at 1, 2, or 3 "clusters," according to its length) and multiplying by 5.3 (average number of leaves per cluster). At the time of thinning, July 5 to 10, the requisite number of fruits was removed from each major limb to give the desired leaf-fruit ratio.

For the Bartlett and Winter Nelis trees fairly uniform thinning of the entire trees was accomplished with experienced assistants without the aid of preliminary fruit and leaf cluster counts. However, for all lower limbs bearing fruits tagged for measurement, final adjustment for precise leaf-fruit ratios was made after actual counts.

[1]This is a report of a cooperative project between the U. S. Department of Agriculture and the Oregon Agricultural Experiment Station.

[2]Published as Technical Paper No. 217 with the approval of the Director as a contribution of the Medford Branch of the Oregon Agricultural Experiment Station.

The Bartletts were thinned on June 22 to 24, and the Winter Nelis on June 28. For all three varieties, terminal shoot growth in length (except some secondary growth about equal in all plots) had practically ceased before thinning.

Average leaf area was estimated by comparing all leaves (from 500 to 1000) on several representative limbs for each variety with leaf-shaped metal discs with areas of 5, 10, 15, 20, 25, 30, 35, and 40 sq. cm., and recording the disc which each leaf most closely resembled in area. By this method average leaf areas were found to be: Anjou, 17.8 sq. cm.; Bartlett, 15.5; and Winter Nelis, 10.8.

Fruit growth, duration of stomatal opening, and shoot diameter were measured as described (2) previously. Limb circumferences of Anjou were measured monthly at marked places on the limbs. All the fruit picked from each tree was measured in picking lugs and termed "total yield." Packout records were obtained by running all the fruit from each plot through commercial packing houses in the usual manner, and recording the number of packed boxes of each commercial size and grade. Anjou and Bartlett culls from each plot were saved and later sorted. The average number of packed boxes of both grades is termed "commercial yield."

A heavy wind storm just before Anjou harvest caused about a .6 lug-box drop from each tree in each plot. No drop from this wind occurred in the Winter Nelis plots.

Results and Discussion

The average rates of fruit enlargement for 3- to 5-day periods are shown in Fig. 1. All three varieties showed pronounced periods of temporary reduction in growth rate. Such a period of reduced growth for all varieties occurred about July 15, which marked the end of a 4-day period with air temperature maxima over 96 degrees F. During this period all Bartlett trees, regardless of leaf-fruit ratio, showed about the same reduction in fruit growth rate. With Anjous, however, trees with 75 l.p.f. (leaves per fruit) showed much less check in fruit growth than trees with 35 or 50 l.p.f. With the Winter Nelis, trees with 80 l.p.f. showed the least check, and trees with 25 l.p.f. the greatest check in fruit growth.

The very pronounced reduction of fruit growth for Anjou between August 5 and 8 occurred during a period characterized by air temperature maxima under 96 degrees F. and by a serious "two-spotted mite" infestation. During this period the trees with 50 or 75 l.p.f. showed less reduction in fruit growth rate than the trees with only 35 l.p.f. The Anjou growth check about August 25 occurred at the end of a period of air temperature maxima over 96 degrees F. The low growth rate in early September occurred during a cool period and cannot be explained.

The reductions in growth rate of Bartlett, about August 16 and again about August 24, occurred during the latter part of periods with air temperature maxima over 96 degrees F. During the second of these two periods there was less reduction in fruit growth rate for the trees with 40 or 50 l.p.f. than for trees with 25 or 30 l.p.f.

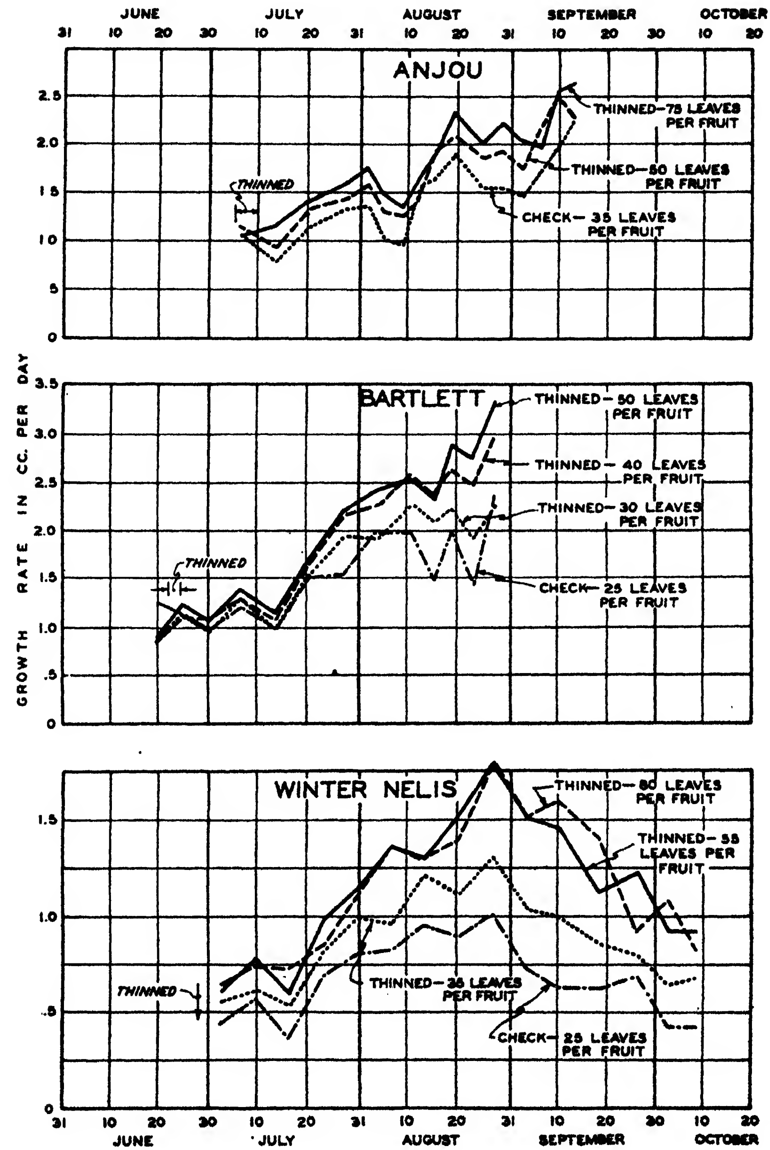

FIG. 1. Effect of thinning upon growth of fruit.

TABLE I—EFFECT OF THINNING ON TOTAL YIELD, SIZE AND GRADE OF FRUIT, COMMERCIAL YIELD, AND LEAF EFFICIENCY FOR FRUIT GROWTH

Treatment (Leaves per Fruit)	Leaf Area per Fruit (Sq. Cm.)	Trees per Plot	Total Yield* per Tree (Lug Box)	Size: Under 180 (Per cent)	Size: 180 to 165 (Per cent)	Size: 150 to 135 (Per cent)	Size: Over 135 (Per cent)	Grade: Ratio Ex. Fancy to Fancy	Grade: Culls* (Per cent)	Culls: Codling Moth (Per cent)	Culls: Limb Rub or Misshapen (Per cent)	Commercial Yield* per Tree (Pk. Bx.)	"Leaf Efficiency for Fruit Growth" cc
	A	B	C	D	E	F	G	H	I	J	K	L	M
Anjou													
Check 35	623	9	10.7	1	9	45	45	—	15	16	L R 25	7.7	.23
Thinned													
50	890	9	9.1	0	2	25	73	—	16	20	25	3.9	.19
75	1335	4	5.7	1	6	25	68	—	10	18	29	3.9	.13
Bartlett													
Check 25	388	3	11.2	11	55	26	8	.95	24	23	44	6.1	.40
Thinned													
30	465	3	10.2	7	28	44	21	.48	18	23	48	6.1	.36
40	620	4	9.2	1	9	34	56	.68	19	32	51	5.8	.31
50	775	3	8.7	1	1	29	69	.42	22	23	63	5.3	.26
Winter Nelis													
Check 25	270	3	19.7	88	11	1	0	1.9	8	—	—	5.9	.25
Thinned													
35	378	3	15.8	40	49	11	0	2.4	10	—	—	10.4	.23
55	594	3	13.4	11	31	55	3	2.5	10	—	—	10.4	.19
80	864	2	12.1	1	36	62	1	2.4	8	—	—	8.9	.13

*Yield for Winter Nelis trees, which varied in size, is expressed as yield per 700 sq. cm. of total scaffold limb, cross sectional area, as used by Fletcher (4).

†Culls do not inlcude fruit too small for commercial pack.

During the summer the fruit growth rate tended to increase. For Anjou and Bartlett the maximum growth rate was reached just before harvest. For Winter Nelis, however, the maximum growth rate occurred about August 25; thereafter until harvest it declined rather rapidly. These trends of growth rate for Bartlett and for Winter Nelis correspond to those found by Magness, Overley and Luce, (7), using ringed limbs.

In the Winter Nelis plots, the failure of the fruit with 80 l.p.f. to grow more rapidly than fruit with only 55 l.p.f. seems peculiar. Since there were only two trees with 80 l.p.f. and one of these was smaller than the trees in the other three plots, too much significance cannot be placed on this peculiar behavior. It is possible, however, that this result may correspond to the observations of Jones (6), who, using ringed peach limbs, found less fruit growth with 60 l.p.f. than with 45 l.p.f.

The total yield and packout records are given in Table I. Column C shows decreased total yield ("orchard run" fruit) with increased thinning. Columns D to G show more fruit of the larger sizes with increased thinning, except for Anjou with 75 l.p.f. This exception is probably attributable to the drop of a large proportion of the larger sizes during the windstorm. Column H, giving the ratio of "extra fancy" to "fancy" grades, shows one peculiar feature,—thinning tended to decrease the proportion of extra fancy Bartletts. Observation showed this to be due to more fruits with knotty, irregular skin surface following increased thinning. From Column I it is apparent that thinning did not consistently reduce the percentage of culls. With Anjous thinning did not reduce limb rub, and with Bartletts thinning increased fruits culled for undesirable shape. The fact that Bartletts, which usually show codling moth entries on fruit left in clusters, showed no consistent reduction in codling moth culls with thinning must be attributed to the thorough spraying with sufficient pressure to provide a complete insecticide coating on fruits in clusters.

Column L gives the commercial yield in packed boxes per tree. For Anjou the unthinned trees, with the largest total yield, also gave the largest commercial yield, because the 36 l.p.f. on the unthinned trees was sufficient to bring all but 1 per cent of the fruits up to 180 or larger. For Bartlett the unthinned trees, likewise with the largest total yield, gave the same commercial yield as the trees thinned to 30 l.p.f., because the unthinned trees had a larger percentage of fruit under 180 and had more culls. However, because of the larger proportion of fruit in the extra fancy grade and of the absence of thinning expense, the unthinned trees were probably the more profitable. Bartletts thinned to 40 or 50 l.p.f. had lower commercial yields than either the unthinned trees or the trees thinned to 30 l.p.f. In Winter Nelis, although no thinning resulted in the greatest total yield, it produced only 12 per cent of fruit 180 or larger. Thinning to 35 l.p.f. or to 55 l.p.f., which resulted in 60 to 89 per cent of fruit 180 or larger, produced a greater commercial yield than no thinning. Trees thinned to 50 l.p.f. had the same commercial yield as those

thinned to 35 l.p.f., apparently because the decreased total yield in the former trees was just compensated by the larger proportion of fruit of 180 or larger. The trees thinned to 80 l.p.f. had a lower commercial yield than those receiving lighter thinning.

The fact that Column C (Table I) shows in each case that thinning decreased the total yield is not particularly convincing, with as few as two or three trees per plot. The literature reports somewhat similar experiments, with apples, showing that in general thinning decreased total yield but in some cases increased total yield. Such inconsistency is in all probability due to variation in tree size in different plots. Recently Ellenwood and Howlett (3), correcting for tree size, found that thinning apples decreased the total yield. Murneek (8), however, using as many as 100 trees per plot, concluded that thinning does not necessarily decrease yield. To study more closely the effects of fruit thinning Column M (Table I) was prepared, showing the average increase in fruit volume per day (from individual fruit measurement data) between time of thinning and harvesting, for each 100 cc of the leaf area per fruit. This so-called "leaf efficiency for fruit growth" was calculated by dividing the total fruit volume increase after thinning by the average leaf area per fruit and by the number of days, and multiplying by 100. Column M shows a very definite decrease in "leaf efficiency for fruit growth" as the number of leaves per fruit were increased by thinning. Therefore, as leaf-fruit ratio was increased by thinning, a given leaf area produced a smaller volume of fruit; and thinning necessarily had to result in a reduction in total volume, or yield, of fruit. Decreased leaf efficiency on ringed limbs with increased leaf-fruit ratios has been reported for apples by Haller and Magness (5); for pears by Magness, Overley and Luce (7); for peaches by Overholser and Claypool (10), by Weinberger (13), and by Jones (6); and for oranges by Shamel, Pomeroy and Caryl (11).

An effort was made in this study to explain this decreased "leaf efficiency for fruit growth" with increased leaf-fruit ratios. Although Weinberger (13) found on ringed peach limbs an indication of longer period of stomatal opening for the smaller leaf-fruit ratios, observations in the Anjou plots on 4 days showed no difference in duration of stomatal opening. Weinberger suggests that the greater carbohydrate concentration in the fruits with increased leaf-fruit ratios, which he and others found, offers an explanation of this decreased "leaf efficiency for fruit growth." However, analyses of fruit from each of these plots, given in Table II, show no effect of leaf-fruit ratio on total sugar content at harvest, and show only a slightly higher content. of acid-hydrolyzable polysaccharides with the higher ratios. Analyses of the terminal 2 inches of the shoots (Table III) likewise show little or no effect of leaf-fruit ratio on carbohydrate content. Therefore, it is not likely that increased accumulation of carbohydrates with the higher leaf-fruit ratios explains the decreased "leaf efficiency for fruit growth" for these entire trees.

Measurement of scaffold limb circumference in two of the Anjou plots during July, however, suggested an explanation. As shown by

TABLE II—EFFECT OF THINNING ON FIRMNESS, AVERAGE VOLUME, AND CARBOHYDRATE CONTENT OF FRUIT AT HARVEST

Treatment	Firmness* at Harvest (Pounds)	Average Volume at Harvest (cc)	Moisture and Carbohydrates as Per cent of Green Weight on August 30, 1933		
			Moisture Per cent	Total Sugars Per cent	Reserve Material† (Per cent)
			Anjou		
Check 35 l p f	16.5±.11	122.9	80.9	7.93	3.37
Thinned 50 l p f	19.5±.11	139.2	81.4	8.19	3.58
75 l p f	20.1±.12	148.9	81.7	7.83	3.80
			Bartlett		
Check 25 l p f	18.9±.08	119.5	85.2	7.16	3.19
Thinned 30 l p f	19.4±.11	128.0	84.8	6.98	3.29
40 l p f	19.7±.10	144.2	84.3	6.88	3.69
50 l p f	20.6±.11	154.4	85.2	6.93	3.82
			Winter Nelis		
Check 25 l p f	———	82.3	80.9	10.12	3.56
Thinned 35 l p f	———	103.9	80.6	10.24	3.35
55 l p f	———	133.9	80.6	9.81	3.87
80 l p f	———	133.3	79.8	10.40	3.90

*Magness and Taylor tester with $\frac{5}{16}$ inch plunger.
†Reserve Material = Total acid hydrolyzable polysaccharides, including starch.

Table III, the increase in cross-sectional area during July of main scaffold limbs of Anjou trees with 50 l.p.f. was slightly greater than for trees with only 35 l.p.f. Measurements for August likewise showed increased limb enlargement with the greater leaf-fruit ratios. Therefore, in October the average shoot diameter for all plots was measured. Table III shows that in most cases the trees with the greater leaf-fruit ratios had greater shoot diameter. Obviously, if thinning results in increased limb and shoot enlargement, foods manufactured by the leaves will be used, and a smaller proportion of the food produced by the leaves will reach the fruits. Thus, whenever thinning results in increased branch growth, thinning must necessarily result in decreased total yield, unless thinning should also result in actually increased efficiency for a given leaf area.

It is interesting that (Table II), with Bartlett and Anjou, increasing the leaf-fruit ratio resulted in slightly greater fruit firmness (differences not always statistically significant). Furthermore, as might be expected, thinning entire trees did not result in the carbohydrate increases in the fruit that have been found (5, 6, 7, 10, 13) when ringed limbs were thinned. It is possible that carbohydrate differences in the fruit would have been found if greater extremes in leaf-fruit ratio had been studied. Winkler (14) found grape thinning

TABLE III—EFFECT OF THINNING ON SHOOT AND LIMB GROWTH AND ON MOISTURE AND CARBOHYDRATE CONTENT OF SHOOTS* (1933)

Treatment	Av. Increase Cross-sectional Area Scaffold Limbs		Average Diameter 1933 Shoot Growth Oct. 26, 1933 (Mm)	Moisture and Carbohydrates as Per cent of Green Weight on Oct. 24, 1933			
	July (Sq. cm.)	August (Sq. cm.)		Green Weight per Shoot* (Gm)	Moisture Per cent	Sugars Per cent	Reserve Material† Per cent
			Anjou				
Check 35 l p f	.67±.046	.05±.030	3.6±.034	.613	50.7	1.97	15.4
Thinned 50 l p f	.89±.055	.20±.027	3.9±.033	.617	51.4	1.62	15.1
75 l p f	——	.46±.047	4.2±.031	.697	51.1	2.01	14.8
			Bartlett				
Check 25 l p f	——	——	3.3±.023	.544	51.6	1.90	14.0
Thinned 30 l p f	——	——	3.3±.023	.528	51.1	1.95	14.5
40 l p f	——	——	3.4±.031	.578	51.6	1.91	14.6
50 l p f	——	——	3.8±.036	.737	52.7	1.98	14.6
			Winter Nelis				
Check 25 l p f	——	——	2.2±.018	.229	48.7	1.71	15.3
Thinned 35 l p f	——	——	2.3±.021	.273	48.8	1.95	14.9
55 l p f	——	——	2.5±.023	.312	48.7	2.11	15.1
80 l p f	——	——	2.5±.025	.317	49.0	2.14	15.5

*Terminal 2 inches of shoot.
†Total acid hydrolyzable polysaccharides including starch.

increased the sugar content of the berries, and Aldrich and Fletcher (1) found 20 per cent more sugar in apples on trees thinned to 100 l.p.f. than on unthinned trees with only about 25 l.p.f.

Likewise, although Murneek (9) found thinning ringed limbs increased the carbohydrate content of the new and old wood, Table III shows that fruit thinning of entire pear trees did not result in appreciable differences in per cent of carbohydrates in the shoot tips. Since thinning did result in larger shoots, thinning obviously resulted in more carbohydrates per shoot. Such results are similar to those found by Waring (12), who thinned entire plum trees; and to those by Aldrich and Fletcher (1), studying spurs of entire apple trees.

SUMMARY

Fruit thinning of entire pear trees, which increased the leaf area per fruit, resulted in increased growth rate of the fruit. However, the increase in fruit growth rate was not in proportion to the increase in leaf area; in other words, thinning decreased total yield. This is explained by the increased limb and shoot growth following thinning, which reduced the amount of food available for fruit enlargement.

Acknowledgments

The irrigation and determination of soil moisture conditions of the Anjou plots were handled by Mr. R. A. Work, of the Division of Irrigation, Bureau of Agricultural Engineering, whose cooperation the author greatly appreciates.

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The Distribution of Total Nitrogen in the Orange Tree

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In this paper are presented data and conclusions regarding the distribution and seasonal fluctuations of total nitrogen in the Valencia orange tree.

Materials and Methods

The conclusions presented are based on data obtained from three series of investigations. Essentially the same technique was used throughout and was briefly as follows: The material, collected at Riverside, California, at intervals throughout the year as indicated in the accompanying tables and figures, was subdivided according to character or diameter into fractions and subfractions as indicated in Table I; dried and ground. Total nitrogen was determined in aliquots of the dried and ground material by the Kjeldahl-Gunning method.

Material for the first series of determinations consisted of fifteen young Valencia orange trees, 3½ years old at the time collections were started (1). To determine whether or not these young trees represented the conditions prevailing in bearing trees a second series of determinations were made using four 10-year-old full bearing Valencia trees dug: two on September 27, 1928, and one each on January 25, and May 10, 1929. To eliminate, in so far as possible, individual tree variability and also to determine whether or not the nitrogen content of the tree could be increased by liberal applications of quickly available nitrogenous fertilizers, a third series of determinations were made. Two branches, approximately 2 cm in diameter at the base, were removed, at weekly or bi-weekly intervals between February 1, 1930, and January 31, 1931, from each of four 12-year-old Valencia trees, two of which had received 5 pounds of actual nitrogen, one in the form of ammonium sulfate, the other calcium nitrate, shortly before the collections were started. This nitrogen, which was additional to that supplied by the regular fertilization—normally about 2 pounds per tree, did not produce a measurable increase in the nitrogen content of either branches or leaves.

As a preliminary to this last series of determinations a careful study was made of the effect of the position of a branch on its nitrogen content. Similar material collected from different parts of the same tree was found not to vary in its nitrogen content by more than the experimental error of such determinations.

Analytical Data

To illustrate the method of fractionation as well as to show the distribution of nitrogen within the bearing tree, all the essential data obtained for one of the 10-year-old trees (that dug January 25, 1929) are presented in Table I. For comparison with this tree, the distri-

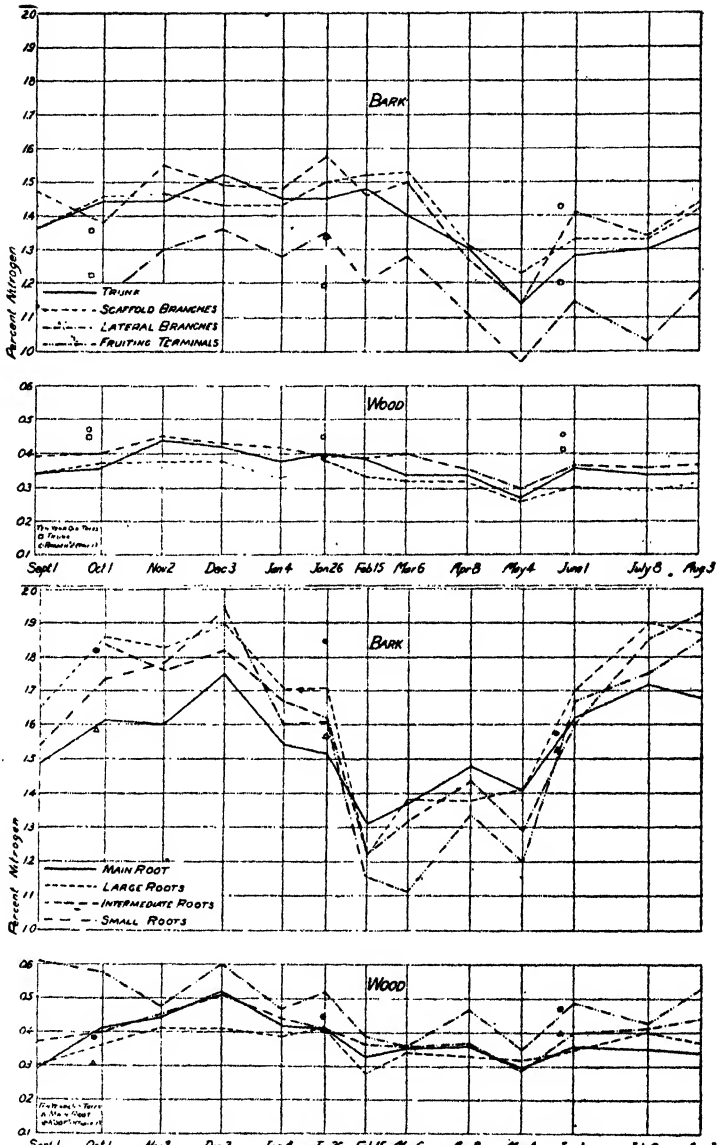

Fig. 1. Seasonal Fluctuations in Nitrogen Content of Young Valencia Orange Trees.

bution of nitrogen in trees dug on September 27, 1928, and May 10, 1929, is shown in two additional columns at the right of the table.

Seasonal fluctuations in nitrogen content of representative parts of the young trees are shown graphically in Fig.1. The data for the older trees are of course too meagre to permit the drawing of continuous curves; however, for comparison with the young trees, a few points representing typical fractions of the older trees have been inserted on the chart. The distribution of nitrogen within the young tree at different periods of the year and the relationship between nitrogen and dry weight is shown in Table II. Since, as indicated by Fig. 1, adjacent similar parts of the tree are so nearly alike in their nitrogen content, a number of fractions have been grouped together to obtain the results presented in Table II.

Because additional soil nitrogen apparently did not influence the nitrogen content of either branches or leaves, average values are presented in Fig. 2, for material collected from the four 12-year-old trees.

Since the trend of the leaf data is almost identical with that shown for the bark, the graph is not included. The values are, of course, considerably higher for the leaves than for bark or wood as indicated in Table I.

Discussion

The fertilization program in citrus orchards in California is designed to supply to the mature bearing tree from 2 to 3 pounds of nitrogen annually. This study represents one phase of an attempt to determine how much of this nitrogen the tree actually uses and when it requires it.

Considering only that part of the soil nitrogen which is taken up by the tree, there are certain losses or uses which must be considered. Removal of the fruit and the shedding of leaves, young fruits, and blossoms, represent important losses. An average crop of oranges removes about 35 pounds of nitrogen per acre or more than 200 grams per tree. We have no accurate data regarding the loss due to leaf shed. Our data show, however, that the leaves of a 10-year-old tree contain about 200 grams of nitrogen and that there appears to be no return of this nitrogen to the tree prior to leaf fall. Analyses of freshly fallen leaves indicate that they are as high in nitrogen content as similar attached leaves. The shedding of blossom parts represents an appreciable loss which will be discussed later. Under uses we may consider utilization in new growth, which is relatively small, and temporary storage.

It was thought that a study of seasonal fluctuations in nitrogen content would give some suggestion as to whether or not the tree stored nitrogen which might be used during periods of active growth. Figs. 1 and 2 and Table II suggest some accumulation during late summer and autumn. This is possibly best illustrated by the percentage of total nitrogen to total dry weight (Table II). It would seem that the apparent increase in nitrogen content during autumn may be appreciable when one considers that there is during this period an increase in dry weight due to the accumulation of starch and possibly other carbohydrates (1).

TABLE I—DISTRIBUTION OF TOTAL NITROGEN IN THREE 10-YEAR OLD VALENCIA ORANGE TREES, WITH ESSENTIAL ANALYTICAL DATA FOR ONE, COLLECTED JANUARY 25, 1929

Fraction	Total Weight of Sub-fractions (Gms)		Per cent Moisture on	Per cent of Total Fraction in Sub-fraction		Per cent of Total Tree in Fraction		Per cent Nitrogen in Sub-fraction		Total Nitrogen (Gms)		
	Fresh	Dry	Fresh Wt.	Fresh Wt.	Dry Wt.	Fresh Wt.	Dry Wt.	Fresh Wt.	Dry Wt.	Jan. 25	Sept. 27	May 21
Leaves Vegetative	4,528	1,798	60.3	15.0	11.5	17.00	19.37	0.87	2.20	39.46	40.07	30.70
Leaves Mature	25,653	13,720	46.5	85.0	88.5			1.02	1.91	261.90	187.65	149.19
Fruit 3–5 cm Pulp	6,638	903	86.4	65.9	51.5	5.67	2.20	0.19	1.41	12.73	72.22	12.15
Rind	3,435	856	75.1	34.1	48.5			0.28	1.13	9.63	34.48	9.27
Fruit 5–7 cm Pulp	33,703	8,662	86.7	66.7	79.5	28.45	13.62	0.32	1.25	108.27	41.41	147.25
Rind	16,852	2,242	74.3	33.3	20.5			0.12	0.88	19.73	4.00	76.16
Terminals Vegetative	2,810	1,433	49.0	84.0	82.6	1.89	2.16	0.65	1.28	18.34	20.56	14.61
Fruit Wood	542	299	44.8	16.0	17.4			0.60	1.09	3.25	5.84	4.78
Branch No. 1 Bark	2,088	919	56.0	31.9	23.4	3.69	4.90	0.64	1.45	13.32	15.99	17.55
2–5 mm Wood	4,457	3,016	35.4	68.1	76.6			0.34	0.50	15.08	10.63	11.47
Branch No. 2 Bark	2,926	1,457	54.9	33.3	26.9	4.94	6.79	0.67	1.34	19.52	14.81	16.74
0.5–1 cm Wood	5,851	3,982	35.0	66.7	73.1			0.31	0.45	17.91	14.45	14.76
Branch No. 3 Bark	2,957	1,434	51.6	20.9	16.4	7.95	10.92	0.54	1.12	16.04	17.23	14.01
1–3 cm Wood	11,173	7,315	34.5	79.1	83.6			0.22	0.38	24.26	23.29	20.54
Branch No. 4 Bark	2,148	981	54.3	11.2	8.9			0.46	1.00	9.77	9.45	9.17
Outer Wood	5,972	3,844	35.6	31.2	34.8			0.23	0.35	13.50	12.55	10.14
3.8 cm Inner Wood	11,014	7,171	34.8	57.6	56.3	10.77	14.96	0.21	0.32	23.33	18.75	18.62

Trunk	Bark	800	344	57.0	6.9	4.6			0.51	1.19	4.09	3.90	4.32
	Outer Wood	2,053	1,300	36.7	17.7	17.6			0.26	0.41	5.33	5.66	5.54
	Intermed. Wood	4,315	2,839	34.2	37.2	38.6			0.24	0.36	10.22	7.33	9.45
	Inner Wood	4,432	2,890	34.9	38.2	39.2	6.53	9.20	0.27	0.42	12.14	11.46	10.91
Main Root	Bark	432	182	58.0	5.6	3.9			0.66	1.57	2.86	2.76	2.81
	Outer Wood	2,251	1,372	39.0	29.2	29.8			0.24	0.39	5.35	5.40	4.86
	Inner Wood	5,027	3,052	39.3	65.2	66.3	4.35	5.75	0.26	0.42	12.82	11.13	11.02
Root No. 6	Bark	308	123	60.2	12.6	8.8			0.72	1.79	2.20	1.98	2.80
4–6 cm	Outer Wood	743	438	41.1	30.2	31.3			0.25	0.43	1.88	2.52	2.49
	Inner Wood	1,411	838	40.6	57.2	59.9	1.39	1.75	0.22	0.37	3.10	2.29	4.36
Root No. 5	Bark	1,186	449	63.0	18.9	12.9			0.70	1.85	8.30	6.38	7.13
2–4 cm	Wood	5,088	3,043	40.3	81.1	87.1	3.47	4.36	0.26	0.44	13.39	10.99	12.19
Root No. 4	Bark	1,321	488	63.1	30.4	23.9			0.56	1.51	7.37	4.03	6.37
1–2 cm.	Wood	3,026	1,565	48.3	69.6	76.1	2.45	2.56	0.27	0.52	8.14	5.24	8.17
Root No. 3	Bark	755	304	59.9	40.6	35.2			0.56	1.39	4.22	1.98	5.82
.5–1 cm	Wood	1,105	560	39.4	59.4	64.8	1.05	1.07	0.35	0.68	3.80	2.04	2.40
Root No. 2—Less than 0.5 cm		520	221	57.5	100.0	100.0	0.29	0.28	0.41	0.96	2.12	1.62	4.46
Rootlets		190	68	64.3	100.0	100.0	0.11	0.08	0.53	1.48	1.00	0.42	1.09
Totals		177,710	80,108								734.41	630.51	683.30

Another reason for assuming that some of the nitrogen present in the tree during autumn and early winter, constitutes a reserve is that the amount lost in shed blossom parts in March and April appears to be greater than that absorbed by the tree during this period. Collection and analysis of all the fallen flower parts from two 12-year-old trees indicates that the loss may amount to as much as 30 grams per tree. Surr (2) has shown that normally the supply of nitrate nitrogen

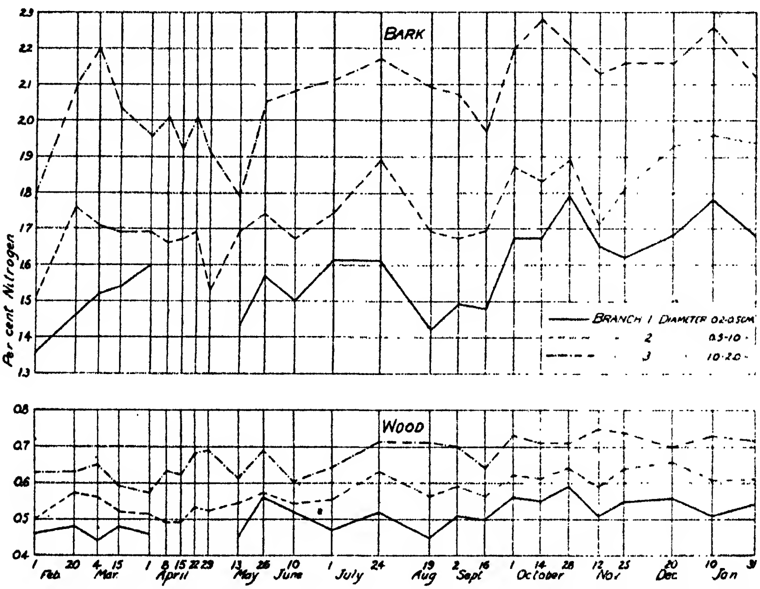

FIG. 2. Seasonal Fluctuations in Nitrogen Content of Branches of 12-year-old Valencia Orange Trees.

in the soil is low in spring and early summer. Probably, then, a large part of the nitrogen present in the blossoms is translocated from other parts of the tree. We believe that this loss will, to a considerable degree, account for the low value of the nitrogen-dry weight percentage indicated for both the 3½ and 10-year-old trees in May (Table II). This low value may explain why the application of quickly available nitrogen in early spring has proved so generally beneficial. In neither case did the trees used for analysis receive applications of "spring nitrogen" during the year of collection of material.

In southern California the orange tree characteristically produces three cycles or flushes of growth each year. In the Riverside section these cycles normally occur during February–March, July–August, and October–November. The effect of this growth activity on the nitrogen content of adjacent portions of the tree is illustrated in Fig. 2. A rather definite decrease in nitrogen content, especially in the bark of branches on which new growth occurs, is evident during these

TABLE II—DISTRIBUTION OF TOTAL NITROGEN AND DRY WEIGHT IN VALENCIA ORANGE TREES* AND THE RELATIONSHIP BETWEEN THEM AT INTERVALS THROUGHOUT THE YEAR

Date	Total (Gms)		Per cent of Total in Above Ground Parts						Per cent of Total in Roots				Per cent Total Nitrogen on Total Dry Wt.
			Leaves		Bark		Wood		Bark		Wood		
	Dry Wt.	Nitrogen	Dry Wt.	Nitrogen	Dry Wt.	Nitrogen	Dry Wt.	Nitrogen	Dry Wt.	Nitrogen	Dry Wt.	Nitrogen	
3½-Year-Old Trees													
Sept. 1	2912.9	33.18	32.2	65.4	11.1	13.6	31.9	9.6	4.0	5.6	20.8	5.8	1.12
Oct. 1	3087.6	34.22	31.0	63.0	8.4	10.0	28.3	9.6	4.9	7.8	27.4	9.6	1.11
Nov. 2	2729.6	34.63	32.1	61.5	8.7	9.8	23.3	7.6	8.5	11.7	27.4	9.4	1.27
Dec. 3	3671.8	45.99	30.5	60.9	9.3	10.0	26.7	8.6	7.2	10.5	26.3	10.0	1.25
Jan. 4	3854.1	43.09	26.5	59.9	9.7	11.7	32.7	10.7	5.8	8.3	25.3	9.4	1.12
Feb. 15	2743.7	26.67	26.0	56.3	9.5	13.1	30.0	11.7	7.6	9.9	26.9	9.0	0.97
Mar. 6	3400.1	33.45	29.5	59.5	9.6	13.3	30.0	10.2	6.3	8.2	24.6	8.8	0.98
Apr. 8	4279.9	43.48	32.4	64.3	7.6	9.3	26.3	8.7	5.8	8.0	27.9	9.7	1.01
May 4	4261.6	34.22	37.5	62.8	9.3	12.5	26.7	9.3	4.2	7.1	22.3	8.3	0.80
June 1	3519.3	34.49	31.0	63.2	9.2	11.6	33.8	11.6	3.0	5.1	23.0	8.5	0.98
July 8	3344.9	33.49	29.9	62.8	8.2	9.9	30.9	9.7	4.4	7.8	26.6	9.8	1.00
Aug. 3	3266.6	34.81	27.2	62.6	8.4	10.0	31.6	10.1	4.4	7.6	28.4	9.7	1.07
10-Year-Old Trees													
Sept. 27	5138.2	478.39	17.86	47.60	12.80	18.35	48.97	21.76	2.11	4.01	18.26	8.28	0.93
Jan. 25	6744.5	584.05	23.01	51.57	10.18	14.45	47.98	20.86	2.72	4.82	16.11	8.30	0.87
May 21	5182.8	438.47	14.65	41.03	11.09	18.51	51.22	23.14	3.70	6.95	19.34	10.37	0.84

*Exclusive of fruit.

growth periods. The most marked decrease occurs during the spring flush, which is the most vigorous of the three and is accompanied by profuse blossoming. The midsummer cycle, less vigorous than the spring cycle, is accompanied by correspondingly less marked reduction in nitrogen content of the parent branches, and the autumn flush, which is characteristically sparse, causes a relatively slight reduction. Our data indicate that corresponding reductions occur in the nitrogen content of the leaves of these branches. Fluctuations are less definite, however, possibly because of the inclusion in the samples of relatively young leaves, high in nitrogen, of the preceding growth cycle. Only leaves of current cycle growth were kept separate.

In view of the fact that some investigators have emphasized the importance of roots as storage organs, it is interesting to note that at no time do the roots contain more than about 21 per cent of the total nitrogen of the tree (Table II). Even excluding the leaves, which contain about 40 per cent of the nitrogen of the 10-year-old tree and approximately 60 per cent of that of the young tree, the above-ground portions of the tree contain as much or more nitrogen than the roots. On a percentage basis the roots, particularly the bark, are richer in nitrogen than the above-ground portions and the fluctuations are much more marked (Fig. 1), but the absolute amounts of nitrogen involved are small. Root bark, in which the widest fluctuations occur, constitutes less than 4 per cent and 6 per cent respectively of the total dry weight of the 3½ and 10-year-old trees. Fluctuations in root wood are only slightly more marked than in wood above ground. It would seem, therefore, that there is little reason to suppose that this is an important storage region. It is our belief that such storage as does occur in the orange tree is mainly in the leaves.

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Resistance to Low Winter Temperatures of Subtropical Fruit Plants

By Robert W. Hodgson, *University of California, Los Angeles, Calif.*

Introduction

An early winter freeze (December, 1932) of unprecented severity and duration in northern California provided an opportunity to observe the resistance of subtropical and semi-hardy fruit plants to low temperatures and the effects which such temperatures produce. Observations were made in July and August, 1933, in some fifty localities where official temperature records or reasonably accurate records from other sources are available. Use has also been made of observations by others, taken shortly after the freeze.

Weather Conditions Preceding and Accompanying the Freeze

With two exceptions, the mean temperature for November, 1932, throughout California was the highest on record for this month and similar weather continued through the first week of December. Both the day and night temperatures were above normal with the day-temperature excess the greater. New record high temperatures for the month were established during the period of the 16th to the 22nd.

The cold wave entered the state from the north December 7 and temperatures dropped rapidly. By the 9th they were much below normal, which continued until the 16th. New absolute minimum temperature records were established generally throughout the Sacramento Valley and as a result the mean temperature for the state was the lowest on record for December. Northern California also experienced the record low mean temperature for all months. The most severe cold occurred from the 10th to the 14th, during which period minimum temperatures as low as 6 degrees F were recorded in some of the fruit-growing districts.

Of comparable freezes with reference to minimum temperatures, this was the earliest of record. The duration of injurious temperatures was also the longest ever recorded for the region. This is illustrated by the record from a thermograph operated in one of the citrus districts, which registered a minimum of 11 degrees F December 11, 51 hours of 20 degrees F or lower and 21 hours of 15 degrees F or lower. The freeze was accompanied by strong, steady northerly winds with an estimated maximum velocity of 30 to 35 miles per hour on the night of the 12th. As a consequence, orchard heating was not effective in preventing loss of crop and tree damage, though it did reduce the degree of injury.

The earliness, suddenness and severity of this freeze, and the weather conditions which preceded and accompanied it all combined to make it the most disastrous on record for northern California.

Observations on the Injury Caused to Fruit Trees

The order of presentation reflects the relative amount of observational evidence obtained in this study. The lowest temperature following the occurrence of which observations were made is given in the discussion for each fruit. Fruits uninjured at the lowest temperatures which occurred are mentioned at the end of the section.

Walnut (*Juglans regia*):—Marked evidence of varietal differences were observed, with the following descending order of resistance: Mayette, Franquette, Concord, Eureka and Payne, Blackmer (Westfal, Mautner, Woodland Pride, etc.). There was practically no injury to Mayette, comparatively little to Concord and Franquette, but injury to Eureka, Payne, and Blackmer was extensive and severe. *Juglans Hindsii* and the Royal and Paradox hybrids were unhurt.

At temperatures of 15 to 16 degrees or higher there was little or no injury. As the temperature decreased the severity and extent of injury increased. Vigorous terminal shoots were the first to suffer injury, followed by killing of weak fruit-wood, injury to or killing of the bark in and adjacent to the main crotches, and the killing outright of vigorous limbs up to 3 or 4 inches in diameter. Severe bark and crotch injury was subsequently followed by extensive bark cracking as new bark developed, or by the death of girdled or partially girdled limbs, in some cases up to 6 or 8 inches in diameter. Discoloration of limb bark, extending to the recent xylem, and the exudation of black sap from the crotches, were widespread. When growth was resumed, most of this discoloration gradually disappeared and the bark tissues recovered their normal appearance. The extent to which this, and the regeneration of new bark, occurred, was remarkable. Old bearing trees were much less injured than younger trees but year-old scions in topworked trees were less injured than scions up to 5 or 6 years of age.

At temperatures of 10 to 12 degrees and lower crotch injury was general and severe. Younger trees of less resistant varieties were badly injured, and many were killed back to the stock (*Juglans Hindsii*). Fruit-wood of both species exhibited discoloration of the pith. Injury was severe at 6 degrees.

Olive (*Olea europea*):—Marked varietal differences were evident, with the following descending order of resistance: Mission, Columbello, Sevillano and Ascolano, Barouni, Manzanillo, Chemlali. There was some injury to Mission and Columbello, but injury to Sevillano, Ascolano, Barouni and Manzanillo was extensive.

At temperatures of 15 to 16 degrees and higher there was little or no injury and that which occurred was confined to very young trees or tender varieties. The severity and extent of injury increased with lower temperatures. The first injury was confined to splitting of the bark on the fine fruit-wood, followed by killing of the smaller wood (and leaves) and vigorous sucker shoots, the occurrence of bark cracks on larger parts, the death of larger branches, injury to or killing of bark areas at or near the main crotches, killing back to or below the head, and in extreme cases killing back to the ground. In localities where the olive knot disease (*Bacterium savastanoi*) occurs

its prevalence and extension were greatly increased, the bark cracks affording an unusually favorable opportunity for the entrance of the organism. Discoloration of the bark, through the cambium, was widespread but recovery to the normal color was rapid in most cases. The rapidity of bark recovery seemed to be related to the amount of uninjured foliage which remained. Young trees were worse injured than old trees though young scions were much less injured than older trees.

At 10 to 12 degrees and lower only a few old Mission trees escaped severe injury. Much or most of the fruit-wood, and foliage was destroyed on tender varieties, and considerable bark injury occurred on the trunks. Some weak trees were killed back severely and young trees were killed to the ground. Injury was very severe at 8 degrees, and some bearing trees were apparently killed.

Citrus fruits:—Marked species and varietal differences were evident with the following descending order of species resistance: mandarine (*citrus nobilis*), bitter orange (*C. Aurantium*), grapefruit (*C. paradisi*), sweet orange (*C. sinensis*), lemon (*C. Limonia*). Seedling trees of the sweet orange were distinctly hardier than trees of named varieties. Significant differences between the Valencia and Washington Navel oranges were not discernible but the latter was notably hardier than the Thompson navel. Lisbon was the hardiest lemon variety observed and Eureka the tenderest, with Villafranca considerably less injured than Eureka. At temperatures of 10 to 12 degrees the Satsuma mandarine (*C. nobilis* bot. var. Unshiu) was not noticeably hardier than the Washington navel orange; indeed a higher percentage was killed back to the bud-union even though the stock was trifoliate orange (*Poncirus trifoliata*). At higher temperatures both the Satsuma and Willow-leaf mandarines were less injured than the navel orange; the Willow-leaf was apparently slightly hardier than the Satsuma. Old trees (30 years and more) were notably worse injured than younger bearing trees, and young nonbearing trees generally were killed to the ground.

At temperatures of 20 to 25 degrees, in heated orchards, there was very little injury to the orange, slight injury to Villafranca lemon, and moderate injury to Eureka lemon, the latter retaining some foliage but smaller growth being killed back 12 to 18 inches.

At temperatures of 15 to 18 degrees, severe injury occurred in both heated and unheated orchards, though in the former the injury was notably less but more variable. Injury was notably worse where the duration of low temperatures was the longest. Grapefruit and orange trees were killed back several feet but often not completely defoliated. Lemons were defoliated and killed back to branches of 3 to 4 inches in diameter. Severe bark cracking occurred.

At 12 to 15 degrees injury was much more severe. Grapefruit and orange trees were defoliated and killed back to the main framework branches or to a foot or two above the main crotch. Some very old orange trees were killed to below the crotch. Lemons were killed back to the main crotch or lower, with very severe bark splitting.

At 10 to 12 degrees injury was very severe. Orange and grape-

fruit trees were killed back to the main crotch or lower, some to the ground. Lemons were killed to the ground.

Fig (*Ficus carica*):—Some evidence of varietal differences was obtained, the apparent descending order of resistance being as follows: Brunswick, white varieties (Kadota, Calimyrna, Adriatic), Mission. No injury to Brunswick was observed but injury to Kadota, Calimyrna, Adriatic and Mission was extensive, though highly variable.

At temperatures of 15 to 18 degrees there was little evidence of injury but the first crop was markedly reduced, evidently from injury to the fruit buds. The severity of injury increased with lower temperatures. The first injury consisted of killing of weak fruit-wood and individual limbs in old trees (Mission particularly), followed by killing of young trees to the ground, injury to terminal growth on young bearing trees, crotch injury on younger trees, killing of medium sized limbs back to the main crotch, and killing of all growth back to main limbs on old trees. Where crotch injury occurred some of the limbs started growth and later died. A characteristic effect on young bearing trees was weak growth or failure to grow at all (excepting suckers at the base) of individual branches up to 3 or 4 inches in diameter where no crotch or bark injury was evident. Most of these limbs, as well as the killing back of terminal growth, seemed to occur on the south side. Old trees and young trees were much worse injured than medium-aged trees (15 to 25 years).

At 10 to 12 degrees and lower well cared for mature trees were not much injured but severe injury occurred to old trees and young bearing trees. Injury was very severe at 6 degrees.

Loquat (*Eriobotrya japonica*):—At 15 to 18 degrees injury was confined to killing of the bloom and some discoloration of bark tissues. Some young fruits escaped injury. At 12 to 15 degrees the bloom and young fruits were killed and bark discoloration was more pronounced. At 9 to 12 degrees there was some killing of fruit-wood, severe bark discoloration and some killing of outer bark. The slowness of clearing up of the bark discoloration was striking in comparison with the walnut and olive.

Pomegranate (*Punica granatum*):—At temperatures above 12 degrees there was virtually no injury. At 9 to 12 degrees some injury occurred though not extensive, but was confined to young plants, of which some were killed to the head, and to plants in a sensitive condition because of weakness or excessive vigor. The injured plants showed crotch injury with some limbs girdled, also some killing of fine terminal growth.

Avocado (*Persea drymifolia*):—At 15 to 18 degrees young trees of the Mexican race were killed to the ground and old trees back to the head or lower. At lower temperatures all were killed to the ground.

Carob (*Ceratonia siliqua*):—At 15 to 18 degrees considerable injury occurred to large trees. The bloom was killed, some of the terminal growth, and severe bark cracking occurred on shoots up to 3 to 5 inches in diameter. Discoloration of bark tissues was

marked and recovery comparatively slow. At lower temperatures severe killing back occurred and at 10 to 12 degrees the trees were killed back to the main crotch or lower.

Feijoa (*Feijoa Sellowiana*):—At 12 degrees and above no injury was observed. At 10 to 12 degrees some plants were injured but most were not. Crotch injury followed by the death of individual branches, appeared to be characteristic, also some killing of fine terminals.

Prickly pear (*Opuntia Ficus-indica*):—There was evidence of varietal differences, some being much more tender than others. In general, the plants were killed to the ground at 15 to 18 degrees and outright at 10 to 12 degrees. Two varieties (unnamed) were virtually uninjured at 16 degrees.

Date palm (*Phoenix dactylifera*):—At 10 to 12 degrees several recently planted offshoots appeared to be killed. At 10 to 16 degrees injury to older plants was confined to killing of most of the leaves. Attached offshoots apparently were not killed. The subsequent bloom was abnormally small and weak.

Guava (*Psidium cattleianum*):—Large plants were killed to the ground at 12 to 15 degrees.

Subtropicals apparently uninjured:—No evidence of injury to the following fruits was observed: Oriental persimmon (*Diospyros kaki*) at 9 degrees, pistachio (*Pistacia vera*) at 10 degrees, Chinese jujube (*Zizyphus Jujuba*) at 10 degrees, European grape (*Vitis vinifera*) at 8 degrees, pecan (*Carya pecan*) at 10 degrees, and almond (*Prunus communis*) at 10 degrees. The latter exhibited browning of the pith in the fruit spurs and buds at 10 to 16 degrees but the crop was normal in all respects.

Injury to temperate zone fruits:—At 10 to 16 degrees the pear showed browning of the pith in the fruit-spurs as did also the sweet cherry and some of the fruit buds of the latter were killed. Crops were normal in both cases. No evidence was found of fruit bud injury in the peach and apricot.

Factors Influencing the Degree of Injury

Marked effects or influences of factors other than minimum temperature, variety, and age of plant were observed. Of these, state of dormancy was apparently one of the most important, particularly with the walnut. Had this freeze occurred a month later, undoubtedly walnut injury would have been slight and the injury to other fruits somewhat less.

The nutritional condition of the trees seemed also to be of special importance, particularly with the olive, orange and fig. Under comparable conditions well cared for olives were apparently worse injured than recently abandoned orchards or plantings in alfalfa sod. Orchards long neglected were injured the worst, however. Well cared for trees carrying excessively heavy crops seemed to suffer more than trees with light or moderate crops. This effect was most pronounced at relatively low temperatures. In several instances injury was dis-

tinctly worse in parts of orange groves which had been irrigated just prior to the freeze. The unirrigated and less injured portions were said to have been slightly wilted at the time of the freeze. Well cared for orange orchards were less injured than neglected or recently abandoned plantings, however. This was also notably true of the fig.

Injury to the fig, and in less degree to the olive, appeared to be correlated with depth of the soil, being much worse on shallow soils. Walnut injury also was somewhat worse on the lighter soils. Areas where trees had been weakened from lack of drainage or excessive irrigation exhibited severe injury. Irrigated figs were less injured than dry-farmed orchards, the least difference occurring on deep and heavy soils.

The effects of exposure to the strong wind which accompanied the freeze and of protection against it were most marked with the citrus fruits and olive. Much less injury occurred where protection was afforded by local topography, windbreaks or buildings. In many cases the difference in degree of injury occasioned by this factor was remarkable. These fruits also exhibited indubitable evidence of the effect of duration of injurious temperatures. At approximately the same minimum temperatures, with other conditions fairly comparable, injury was much more severe where damaging temperatures persisted the longest.

Methods of Protecting Trees from Winter Injury

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THE waxy coatings and the possible efficiency of trichomes in limiting water loss from desert plants suggested the application of some substance which would resemble these plant structures and perhaps protect in some measure from low temperature injury. Obviously, any artificial exterior layer would have but little direct effect in preventing the escape of cell water because of the intercellular spaces into which the water might pass. It is then clear that coverings could act for the most part only indirectly by impeding the final moisture liberation from the plant. Retarding the ultimate release of water at the plant surface seemed to offer some probability of conserving the water content of protoplasm to bring about increased hardiness.

Rosin emulsion as a water resistant adhesive together with short asbestos fibre which is somewhat deliquescent were employed to give a resinous surface film and the desired persisting dense pubescence. The rosin emulsion was prepared by adding 146 grams of sodium resinate to 78 grams of powdered rosin with enough cold water to make a paste. The mixture was heated and stirred constantly until it assumed a smooth greasy yellow appearance. Enough water was then added to make a quart of a very stable emulsion, which was used full strength as a spray.

Preliminary trials with cabbage plants demonstrated that the spray alone without asbestos killed the leaves. When asbestos was also applied, little or no injury was observed. Similar treatment of Elberta twigs showed killing back when the spray alone was used but no bad effects followed if the asbestos absorbed the excess emulsion.

In a series of nine separate trials in which a total of 2,200 Elberta fruit buds on excised twigs were frozen, about half of which were emulsion-asbestos covered, 22.91 per cent of the controls and 23.16 per cent of the asbestos covered buds were uninjured. In some of the tests more of the covered buds would be unharmed and again it would be the controls which suffered least. In one freezing of 166 covered and 191 untreated buds, making a total of 357, only one remained alive and it was from the control group. For this material under the conditions of the experiment no protection was afforded by the asbestos.

The white color of the asbestos reduces the internal temperature in the tree especially from 1 to 3 o'clock in the atternoon. As was to be expected, this delayed the blooming date of the plum, pear and apple from 3 to 6 days. Reduction in susceptibility to winter sunscald would doubtless follow trunk applications of asbestos.

Elberta and Georgia Belle peach trees sprayed with rosin emulsion and dusted with asbestos in November lost all of their fruit buds during the prolonged cold weather of February 7, 8, and 9, 1933.

The minimum temperature of —10 degrees F. occurred in the early morning of February 8. At 4 o'clock in the afternoon of February 8, branches were gathered from treated and check trees and placed in the greenhouse.

Examination after 3 days showed that all Elberta fruit buds were dead and that all Georgia Belle fruit buds not covered with water were killed. Asbestos covered Georgia Belle buds thawed in and kept under the water showed 83.8 per cent killing, while 88.6 per cent of the untreated controls were dead. This protection of approximately 5 per cent by the emulsion-asbestos coating probably was due to delayed development as a result of white color rather than to any cell water conservation during the low temperature test.

Except for the factor of white color, the feasibility of increasing hardiness even on an experimental scale through the emulsion-asbestos treatment lies considerably in doubt.

Ripening Dates of Grand Duke Plums on Various Understocks

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ABOUT 12 acres in the University orchards at Davis have been planted to the leading varieties of plums, peaches, apricots, and almonds, on ten different rootstocks. These range from 5 to 10 years of age. To provide material for further study of graft affinities and reciprocal influences, we have topworked mature trees to many common varieties. These plantings are beginning to yield interesting information on reactions between stocks and scions.

Table I gives the 1933 data for the Grand Duke plum grafted on trunks of four peach (on peach roots) and three plum (on Myrobalan roots) varieties, and on seedling roots of Myrobalan, peach, apricot, and almond. The Grand Duke tops range in age from 7 to 9 years. Those worked directly on seedling roots, were 1-year-old Grand Duke nursery-budded trees when planted, and the unions are now slightly below ground. Trees on trunks of peach and plum varieties were developed from grafts placed the year after planting, either high on the main trunk or a short distance out on the primary branches.

Formosa and Wickson are Japanese plums (perhaps salicina x Simonii), and Grand Duke and Robe de Sargeant are European (domestica) varieties. In our experience, the Japanese plums usually do well on domestica plums, but the domestica plums seldom prosper on Japanese stocks. Most varieties of both types perform satisfactorily on seedling roots of Myrobalan and peach, and some do well on seedling roots of apricot and almond. Grand Duke is satisfactory on all four stocks.

In the summer of 1932, the Grand Dukes on trunks of the peach varieties and on Wickson plum ripened their fruits approximately 1 day earlier than those on Formosa plum and Robe de Sargeant prune, and 2 to 3 days earlier than those worked at the ground on seedlings of peach, apricot, Myrobalan, and almond.

On Wickson and Formosa the Grand Duke grafts are quite dwarfish and the leaves slightly chlorotic. Those grafted on trunks of peach varieties are greatly enlarged above the unions, and some of the trunks are badly sunburned on the south and west sides. One Grand Duke tree (1-B) on Early Crawford peach trunk was unthrifty in 1932, and its fruits ripened about 7 days earlier than those on its thrifty companion. In 1933, when this tree regained its vigor, its fruits ripened at the same time as those on the other. There was no difference in the size of the crop on the two trees. Similarly, although in 1931 the fruit on one of the Grand Duke (40-C) on Wickson ripened 7 days earlier than that on its companion (40-D), in 1932 and 1933 the fruit on these two trees ripened at the same time.

As shown by the table, early ripening occurred in cases of uncongenial combinations, abnormal unions, and partial girdling. Thus in 1933, in the case of two Grand Duke trees on Salwey peach

TABLE I—Ripening Date, Condition and Behavior of Grand Duke Plum Trees, University Farm, Davis, California, 1933

Row and Tree	Stock	Age (Years)	Trunk Cir. (Cm)	Ripening Date 1933	Size of Crop	Average Weight of Fruit (Gms)	Enlargement of Union	Condition of Tree
1-K	Salwey trunk	10	38	8/4	L-M	55	Much	Sl. dwft., healthy.
1-M	Salwey trunk	10	33	7/31	H	51	Much	Dwft., unhealthy.
1-E	Elberta trunk	10	29	8/2	M	54	Much	Dwft., trunk sunburned.
1-B	Early Crawford trunk	10	42	8/6	M-F	58	Much	Sl. dwft., healthy?*
1-D	Early Crawford trunk	10	44	8/6	M-F	52	Much	Sl. dwft., healthy?
1-H	Mayflower trunk	10	38	8/3	L-M	54	Slight	Dwft., trunk sunburned.
1-J	Mayflower trunk	10	59	8/6	L-M	61	Slight	Normal-sized, healthy.
40-C	Wickson trunk	8	23	8/2	L	58	Slight	Dwft., chlorotic, sunburned.†
40-D	Wickson trunk	8	26	8/2	L	72	Slight	Dwft., chlorotic, sunburned.†
40-B	Robe de Sergeant trunk	8	30	8/7	M	53	None	Normal-sized, healthy.
1-N	Formosa trunk	10‡	68	8/4	L	54	Slight	Dwft., sl. chlorotic.
1-O	Formosa trunk	10‡	56	8/3	H	60	Slight	Dwft., sl. chlorotic.
25-N	Peach seedling roots	9	44	8/5	H	60	Slight	Normal-sized, healthy.
25-O	Peach seedling roots	9	46	8/6	H	54	Slight	Normal-sized, healthy.
14-P	Myrobalan seedling roots	8	44	8/6	L	67	None	Normal-sized, healthy.
14-Q	Myrobalan seedling roots	8	50	8/7	L	60	None	Normal-sized, healthy.
36-P	Apricot seedling roots	8	42	8/8	M-F	53	None	Normal-sized, healthy.
36-Q	Apricot seedling roots	9	43	8/7	M-F	52	None	Normal-sized, healthy.
22-R	Almond seedling roots	8	39	8/6	M	55	None	Normal-sized, healthy.
22-S	Almond seedling roots	8	35	8/6	M	54	None	Normal-sized, healthy.
22-S	Wire-girdled branch			7/31	L	88	None	Chlorotic.

Gr.—greatly; Sl.—slightly; L—light crop; M—medium; F—full or normal; H—heavy; dwft.—dwarfed.

*Unhealthy in 1932; fruit ripened earlier than on the companion tree.

†Some dying-back at tips of branches. Tree 40-D is more severely sunburned than is 40-C.

‡The original grafts soon died in 1-N, and it was regrafted in 1932. In the case of 1-O, only two grafts held. The remaining branches were regrafted in 1932. Large Formosa branches were allowed to develop. and this fact perhaps accounts for the large size of the tree, Formosa being a very vigorous grower.

trunks, the fruits on the dwarfish and unhealthy tree ripened 4 days earlier than those on the more healthy companion. In the two Mayflower trees, the Grand Duke fruits on the sunburned one ripened 3 days earlier. Likewise, early ripening occurred on the dwarfed and sunburned Elberta peach and Wickson plum, while on Robe de Sergeant prune the tree is normal in size, the graft union is inconspicuous, and the fruit is in the late-ripening group. In the late group are the healthy individuals of the combinations discussed above, and those budded at the ground on seedlings of Myrobalan, peach, almond, and apricot.

In 1932, the Grand Duke on seedlings of Myrobalan and almond ripened last. In 1933; those on seedlings of Myrobalan and apricot were the latest, but even with these the fruits were only 1 to 2 days later than those on the other healthy combinations.

No easily recognizable differences appeared in the quality of the fruit from the various combinations. As to size, the only very outstanding instances were very large fruit on a wire-girdled branch, and on the dwarfed and sunburned tree on trunks of Wickson plum.

The effects of partial mechanical girdling were observed in cases of sunburned trunks, bark cankers, and wire girdling. Enlarged unions and loosely-knit unions perhaps constitute partial girdling effects.

Fruit on a wire-girdled secondary branch of Grand Duke grafted at the ground on an almond seedling (22-S) ripened 6 days earlier than the fruit on the remainder of the tree. The fruit was larger, averaging 89 grams as against 54 grams on the normal branches. Though the leaves on this branch were chlorotic, the fruit was apparently of normal quality.

In Placer County, on July 26, 1933, a Grand Duke branch nearly girdled by a canker of bacterial gummosis carried fruit too ripe for shipping while that on the balance of the tree was in prime condition—a difference of perhaps 7 days.

Some years ago in Placer County there was considerable discussion of propagating Grand Duke and President plum on Formosa plum scaffolds. The early ripening from this combination in several instances gave considerable advantage in the market over the later ripening fruit. Some growers also claimed that the Grand Duke topworked upon early peach varieties gave earlier ripening fruit than that topworked on late varieties. Inquiry last summer at two of the larger fruit shipping associations elicited, however, the information that Grand Duke and President topworked on Formosa proved very short-lived (beginning to die in 3 to 4 years) and that growers were not disposed to continue with these combinations. We learned of only two trees surviving to date, and these had deteriorated badly; nor could we learn of any grower harvesting early Grand Duke and President plums as a result of topworking on early peach varieties rather than late ones. In this latter connection, the table shows that Grand Duke fruits on Mayflower trunks did not ripen earlier than those on the Salwey. Instances of earliness on peach trunks seem to result from some physical obstruction to sap flow rather than from any qualitative influence.

In all instances of enlarged unions, the swelling was in the scion part immediately above the union, and in some cases this part was growing down over the stock. In some of the Formosa-Grand Duke grafts the tissues are so loosely knit that a knife may be thrust readily between them nearly to the center of the branch.

The date of ripening was arbitrarily selected as that on which practically all of the fruit on the tree was ready for eastern shipment. At that time nearly all specimens had a little bluish bloom around the stem end.

It may not be out of place to mention here that we have President plums (domestica) on several seedling roots, and topworked in scaffolds of eight varieties of Japanese and eight European plums. The grafts in the topworked trees are mostly 3 years of age. Very little difference in the ripening dates was observable in these various combinations with the President plum. As with the Grand Duke, fruits on scions worked on varieties were generally 2 to 3 days earlier than on those worked directly on seedling roots. On Kelsey plum (a Japanese variety) the President grafts were dwarfish, with enlarged unions, while the fruit was very large and about 4 days earlier than on Myrobalan roots.

Trials With Pear Stocks in New York[1]

(Preliminary Report)

By H. B. Tukey and K. D. Brase, *Experiment Station, Geneva, N. Y.*

THE common cultivated pear (*Pyrus communis* L.) also called the European pear and French pear, has been used universally in the Western world as a stock for pears. It has been recommended by an abundant seed and seedling supply, by uniformity of seedlings, and by good union with cultivated varieties. It has, however, several serious faults, such as: (a) susceptibility of seedlings in the nursery to pear woolly aphis (*Eriosoma pyricola*) and leaf spot (*Fabraea maculata*), the latter frequently resulting in complete defoliation in mid-summer; (b) extreme susceptibility to blight (*Bacillus amylovorus*) both in the nursery and in the orchard. In the search for improved pear stocks, *P. betulaefolia*, *P. calleryana*, *P. serotina*, and *P. ussuriensis* have been included as likely possibilities, worthy of trial (3).

Pyrus betulaefolia is a widely distributed native of northern and central China. It is recommended by abundant seed production, by vigor of seedlings, freedom from leaf spot and woolly aphis, by production of specially vigorous nursery trees, by adaptability to a wide range of climatic conditions, and by a fair degree of resistance to pear blight.

Pyrus calleryana is a native of central China, introduced in 1908. It has been recommended as a potentially desirable stock by vigorous growth of the seedlings in the nursery, good union with varieties of French pear, production of vigorous nursery trees, and high degree of resistance to pear woolly aphis and pear blight. It has been suspected of tenderness to winter cold because it is not found outside the more favored sections of its home.

Pyrus serotina is a native of China and Japan, introduced about 1840. It is one of the parents of Kieffer and related varieties and has been used longer in the United States as a pear stock than any other oriental species, particularly in the South and on the Pacific Coast. It has been recommended by seedlings which are more vigorous than those of French pear, more resistant to pear woolly aphis, and, in some sections, more resistant to leaf spot; by ability to unite easily and well with practically all varieties and species of pear; and by production of vigorous nursery trees. These assets are offset by reports of a greater susceptibility to winter injury and tendency of fruit of the cion variety to develop black-end disease on the Pacific Coast.

Pyrus ussuriensis is a native of northern China, Manchuria, Korea, and southeastern Siberia. Certain varieties of the species are recommended as stocks by their extreme hardiness; by resistance to blight and pear woolly aphis; by their abundant seed production; and by the

[1]Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 19.

vigor of their seedlings. The species falls short in the wide variation in desirable characters of seedlings unless produced from seed of selected varieties, and the tendency of fruit of the cion variety to develop black-end disease.

Because of plant quarantine restrictions which have prohibited the importation of seedling rootstocks of French pear, the desirability of seedlings of domestic varieties has been considered. Among these are Bartlett, recommended by an abundant seed supply from canning factories; and Winter Nelis, recommended by a fair seed supply and seedlings somewhat resistant to blight.

To test these stocks under New York conditions, four varieties of pear, namely, Bartlett, Seckel, Beurré d'Anjou, and Kieffer were propagated and grown on eight seedling root stocks, namely, *Pyrus betulaefolia*, *P. calleryana*, *P. serotina*, *P. ussuriensis*, *P. communis* (imported French pear), *P. communis* (domestic French pear seedlings), *P. communis* var. Bartlett, and *P. communis* var. Winter Nelis. All stocks and varieties were identified as true to species and variety. The trees were planted for trial as 2-year-old nursery trees in 1931, 10 feet apart in rows 10 feet apart, on uniform Ontario clay loam.

The number of trees of each variety on each stock were 6 Bartlett, 5 Beurré d'Anjou, 5 Seckel, and 5 Kieffer, with the exception of *Pyrus serotina*, where no Beurré d'Anjou and 10 Kieffer were included. Since not only the trees but also some of the seedlings were propagated at Geneva, the records deal with 6 to 7 growing seasons, although the trees have been set in the orchard only 3 years. Although this period is too short to warrant final recommendations as to superior stocks, the data are presented in a preliminary way for what help they may be to other workers in this field and to point out some stocks which already have proved unsatisfactory.

The comparative size of the trees after 3 seasons growth in the orchard is shown by the measurements of trunk diameters (Fig. 1). In addition, the following observations may be made.

1. *Pyrus communis* rootstocks have been uniformly successful for all varieties (1). The trees show good vigor, no mortality among 84 planted, and general uniformity. This is true for all four varieties whether on imported French pear seedlings, domestic French pear seedlings, domestic Bartlett seedlings, or domestic Winter Nelis seedlings.

2. *Pyrus betulaefolia* has produced Bartlett, Seckel, and Kieffer trees which are outstanding in size, vigor, and early fruiting; but Beurré d'Anjou trees on this rootstock are uncongenial, being weak and unsatisfactory, one having died. Since the seedlings have been free from leaf spot during five successive seasons as compared to the frequent defoliation of French pear seedlings during the budding season, this species deserves further trial in the East, keeping in mind the factor of uncongeniality and black-end disease (4) which may develop.

3. *Pyrus calleryana* has been worthless for all four varieties, producing weak, tender trees (1) with some mortality.

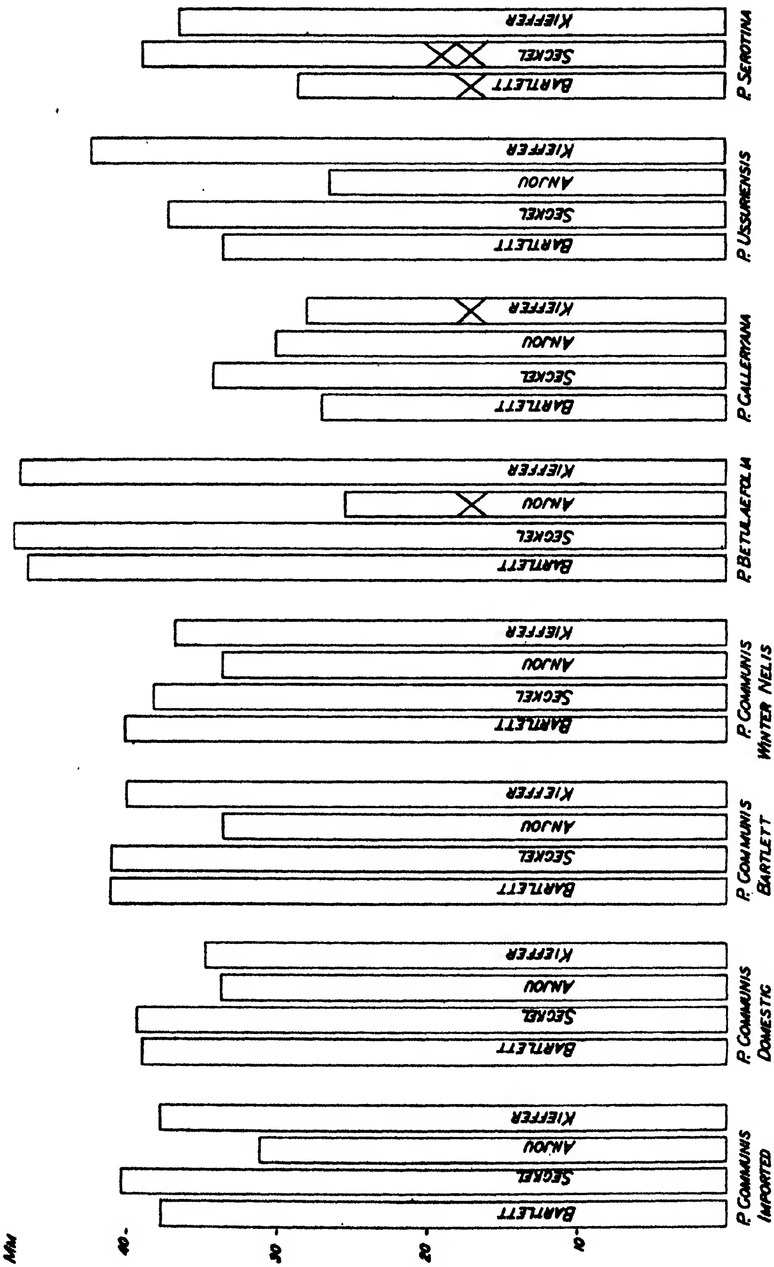

FIG. 1. Trunk diameters of four varieties of pears on eight rootstocks. Dead trees designated "X."

4. *Pyrus ussuriensis* has been satisfactory for its near relative, Kieffer, producing large, vigorous trees; Beurré d'Anjou has made weak growth upon it; and Bartlett and Seckel have made weaker growth than on *P. communis* and *P. betulaefolia*.

5. *Pyrus serotina* has been satisfactory for its close relative, Kieffer, but has been unsatisfactory for Bartlett and Seckel, producing weak trees with some mortality.

It is of interest that Kieffer, a hybrid with *Pyrus serotina* has been relatively more successful on the oriental stocks (5) than have Bartlett, Seckel, and Anjou, which are pure *P. communis* while the three last have been successful in turn upon French roots. The favorable report for domestic seedlings of Bartlett and Winter Nelis is of value at this time because of the quarantine regulations which compel domestic production of rootstocks.

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The Effect of Various Low Temperatures Upon the After-Ripening of Fruit Tree Seeds

By I. C. Haut, *Oklahoma A. and M. College, Stillwater, Okla.*

It is known that a period of after-ripening subsequent to maturity is essential to germination in seeds of most of the deciduous fruits. An exposure to a period of low temperature provides the treatment by which the after-ripening processes are completed.

This paper presents data showing the relative effectiveness of various low temperatures, for different periods of time, upon the after-ripening and subsequent germination in fruit tree seeds.

Five kinds of seed were used, namely, Kieffer pear, McIntosh apple, Late Crawford peach, and Mazzard and Mahaleb cherries. Immediately upon harvesting, the seeds were dried at room temperature and allowed to remain in an air-dried condition for approximately 2 months. They were then soaked for 48 hours after which each kind was divided into five lots and mixed with fine, clean sand. In the peach and Mazzard the endocarp was removed immediately prior to stratification. Lots I were stored at —3 degrees C; Lots II were alternated between —3 degrees and +3 degrees C; Lots III were stored at 0 degrees C; Lots IV at +3 degrees C; and Lots V at +8 degrees C. In the case of Lots II, 10-day alternations between the —3 degrees C and +3 degrees C temperatures were used for the apple and pear seed, and 15-day alternations of these temperatures for the seed of peach, Mazzard and Mahaleb. The —3 degrees C temperature preceded the +3 degrees C temperature at the beginning of these alternations.

At intervals during the storage periods, seed of each kind were removed from the various lots and germination tests were made in order to determine the progress of after-ripening under the various temperature conditions. Five 15-day periods were used for the pear seed; five 20-day periods for the apple; five 22-day periods for the Mahaleb; and five 25-day periods for the Mazzard and the peach. Fifty seeds of peach and 100 seeds of apple, pear, Mazzard, and Mahaleb, respectively, were used for each germination test.

In making the germination tests, the seeds were placed in sand contained in flats. To secure uniform spacing and coverage, each seed was placed individually with the hilum down, by means of forceps. The percentage germination was recorded at 2-day intervals beginning with the appearance of the first seedlings. The germination counts were continued until the maximum germination for a given test was obtained. The results are reported in Table I.

Table I shows that for the seeds of Kieffer pear temperatures of 0, 3, or 8 degrees C are effective for after ripening, while both the alternating and —3 degree C temperatures proved much less effective. The table also discloses that a temperature of 3 degrees C is more effective than either 0 or 8 degrees C.

TABLE I—EFFECT OF VARIOUS LOW TEMPERATURES ON AFTER-RIPENING OF SEED

Lot Number	After-ripening Temperature Degrees C.	Number Seeds for Each Test	Per cent Germination When After-ripened for days Indicated					
			Kieffer Pear					
			Check	15	30	45	60	75
I	-3	100	0	17	19	25	23	17
II	-3+3	100	0	16	15	17	20	22
III	0	100	0	37	53	70	72	77
IV	+3	100	0	55	69	89	97	96
V	+8	100	0	50	64	79	91	93
			McIntosh Apple					
			Check	20	40	60	80	100
I	-3	100	0	0	1	0	5	9
II	-3+3	100	0	1	9	15	10	13
III	0	100	0	8	26	71	75	77
IV	+3	100	0	7	52	91	97	94
V	+8	100	0	5	34	70	79	86
			Mazzard Cherry					
			Check	25	50	75	100	125
I	-3	100	0	0	6	11	10	9
II	-3+3	100	0	3	11	7	8	13
III	0	100	0	5	20	41	53	56
IV	+3	100	0	8	19	65	79	84
V	+8	100	0	6	13	42	59	69
			Mahaleb Cherry					
			Check	22	44	66	88	110
I	-3	100	0	2	0	7	5	10
II	-3+3	100	0	2	16	14	17	24
III	0	100	0	9	29	53	69	74
IV	+3	100	0	8	45	73	89	88
V	+8	100	0	0	30	49	62	69
			Late Crawford Peach					
			Check	25	50	75	100	125
I	-3	50	0	14	12	18	16	16
II	-3+3	50	0	12	14	14	22	16
III	0	50	0	40	70	82	88	84
IV	+3	50	0	44	68	86	86	88
V	+8	50	0	32	54	72	88	90

These same general conclusions may be drawn from the results obtained for apple, Mazzard, Mahaleb and peach. However, with these seeds the —3 degrees C temperature proved even less effective than in the case of the pear, which apparently will after-ripen over a somewhat wider range of low temperature. Both Tukey (3) and Crocker (1, 2) have reported that freezing, or freezing and thawing temperatures, are relatively ineffective for the after-ripening of certain of these fruit-tree seeds.

From the standpoint of nursery practice, 8 degrees C is not a desirable temperature for, although after-ripening occurs, it permits germination during the storage period. It is then usually very difficult to avoid injury either while removing the seeds from the medium or during subsequent handling and planting.

A further study of the data in Table I discloses that high germination was obtained following 45 days of after-ripening at 3 degrees C with the Kieffer pear, and following 60 days for the McIntosh apple, 100 days for the Mazzard cherry, 88 days for Mahaleb cherry, and 75 days for the Late Crawford peach. Although with each of these seeds good germination was obtained following after-ripening at 0 and 8 degrees C in most cases the time required was somewhat longer than that required at 3 degrees C.

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The Effect of Size and of Seed Parent on the Growth of Pear Seedlings

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SOME 5 or 6 years ago there was considerable interest in California in the practice of inarching young seedling pear trees onto mature bearing trees in the hope of curing or decreasing the production of black-end fruits by these trees. Data (1) secured on the growth of young inarched seedlings for 3 years after the inarching showed that not only was there a large variation in the growth of individual seedlings but that the actual growth increment made during these 3 years was small; the inarched seedlings had scarcely doubled in size after 3 summers' growth. Many reasons, such as inherent vigor, or original size of the seedling, character of the graft union, or competition between the roots of the young seedling and the mature tree, could apparently explain the small growth; no actual data were available. The investigation reported in this paper was planned to determine the amount of growth that pear seedlings of different sizes and seed parents might make when placed under good growing conditions and reasonably free from competition.

Tukey and Brase (2) and Webber (3) have reviewed the literature dealing with the variations among trees and some of their probable causes. The natural vigor of the rootstock, as one cause of variation among orchard trees, has received considerable attention. Investigators along this line have assumed that the changed environmental conditions in the nursery row, such as freedom from crowding, would allow the naturally vigorous or naturally dwarfing tendencies to be more freely expressed. Most of the data obtained have been in terms of size of the seedlings or young variety trees. The evaluation of the data has been largely confined to the relationships existing between the size of the seedling at the time it was removed from the seed-bed and its size at the end of one year in the nursery row, or the relation between the size of the seedling and the size of the 1- or 2-year-old variety top.

The seedlings used in this investigation were grown by the Staten Island Land Company from Beurré Hardy and Winter Nelis seeds taken from trees planted as pollinizers in a Bartlett orchard. In 1930, the year when the seeds were collected, the Hardy and Nelis varieties bloomed a few days ahead of the Bartlett, although there was some coincidence of bloom. Since the pollinizing varieties were not in the same block any cross pollination would be by Bartlett. The seeds were planted in February, 1931 in rows about a foot wide and several hundred feet long. The young trees were well irrigated during the growing season of 1931. The stand was excellent so that seedlings of a wide range in size were growing very close together. The young trees were dug in January, 1932, all sizes being taken for replanting. They were brought to the University Farm, tops trimmed

and cut back to a length of about 6 inches and the roots to about 4 inches. In February the young trees were planted 4 feet by 4 feet with a dibble on a plot that had previously been leveled for basin irrigation. The plot consisted of 111 rows of 15 trees per row. The odd rows were planted with Winter Nelis and the even rows with Beurré Hardy seedlings. Soon after the planting the diameter of each seedling, 1½ or 2 inches above the ground, was measured. Soon after growth started all buds except the strongest top bud were rubbed off and an attempt made to keep the seedling "feathered" below this point for the remainder of the season. The seedlings always had available water. Two diameter measurements were made at the end of the 1932 growing season; one at the same point as at planting time and the other at the base of the new shoot. The difference between the cross section area of the seedling in the autumn of 1932 and that in the preceding spring, along with the diameter of the new shoot, represent increments of growth made during the first season after transplanting. Seven hundred and ten Winter Nelis and 667 Beurré Hardy seedlings remained at the end of the first season. Only the data for these trees have been used in the calculations.

TABLE I—DISTRIBUTION OF SIZES OF WINTER NELIS AND BEURRÉ HARDY PEAR SEEDLINGS AT THE TIME OF TRANSPLANTING FROM THE SEED-BED

Diameter of Seedling (Mm)	Number of Seedlings		Diameter of Seedling (Mm)	Number of Seedlings	
	Winter Nelis	Beurré Hardy		Winter Nelis	Beurré Hardy
2.0-2.9	2	19	10.0–10.9	31	5
3.0-3.9	61	67	11.0–11.9	15	1
4.0–4.9	101	121	12.0-12.9	5	2
5.0–5.9	127	148	13.0-13.9	5	1
6.0–6.9	107	140	14.0–14.9	3	—
7.0–7.9	109	81	15.0–15.9	2	—
8.0-8.9	90	59	16.0-16.9	1	—
9.0–9.9	51	23			
			Average size	6.8	5.9

The data for the distribution of sizes and the average size of the two groups of seedlings are presented in Table 1. The distribution approximates a normal one and includes a wide range of sizes. At the end of the first summer's growth the Winter Nelis seedlings had an average diameter of 15.2 mm and the Beurré Hardy seedlings an average diameter of 15.0 mm. The diameter of the new growth made from the top bud was, in Winter Nelis seedlings, 14.3 ± .09 mm and for the Beurré Hardy seedlings 13.7 ± .08 mm.

The uniformity of behavior of the two sets of seedlings and the apparently random distribution of sizes suggested that the number of seedlings could be materially reduced. Accordingly, in September, 1932, the trees were treated as follows: rows 1 and 2 were left unbudded; 3 and 4 were budded to Beurré Bosc; 5 and 6 to Hardy; 7 and 8 to Bartlett, and 9 and 10 to Winter Nelis. The same sequence of two rows of unbudded seedlings and two of each variety was con-

tinued throughout the entire 111 rows. Each pair of budded or unbudded rows included one of Winter Nelis and one of Beurré Hardy seedlings. The uniform size of the various groups is shown in Table II. Further evidence of the representative nature of the grouping is shown by the coefficient of correlation, r. This coefficient for original size and diameter of new shoot growth for all Winter Nelis seedlings is .15 ± .02, for the unbudded group .24 ± .05; r for original size and diameter of new shoot growth for all Beurré Hardy seedlings is .08 ± .03, for the unbudded group .13 ± .05; r for original size and area increase the first year for all Winter Nelis seedlings is — .02, for the unbudded seedlings — .07; r for original size and 1-year area increase for all Beurré Hardy seedlings is — .048, for the unbudded seedlings — .01.

TABLE II—AVERAGE DIAMETER JUST ABOVE THE SURFACE OF THE SOIL IN MM. OF VARIOUS GROUPS OF SEEDLINGS AT THE END OF THE FIRST SUMMER'S GROWTH

Seedling Stock	Group Budded to:				Unbudded Seedlings
	Beurré Hardy	Winter Nelis	Bartlett	Beurré Bosc	
Winter Nelis. .	15.22±.23	14.97±.20	15.5±.21	15.17±.243	14.97±.189
Beurré Hardy.	15.48±.195	15.03±.20	15.43±.197	14.53±.192	14.36±.170

All Winter Nelis seedlings—15.17.
All Beurré Hardy Seedlings—14.96.

In the spring of 1933 the tops were cut off the budded trees; the unbudded trees were left untouched. About 300 each of the Winter Nelis and Beurré Hardy tops were weighed. In November, 1933, the diameter of all trees was measured at the same point as in 1932. The diameter of the variety top a short distance above the point of budding was also measured.

Table III presents the data for the diameter of the two stocks under the four varieties, for the unbudded seedlings and for the variety top at the end of the first season after budding.

TABLE III—DIAMETER (IN MM.) OF THE TWO STOCKS UNDER DIFFERENT VARIETIES, OF THE UNBUDDED SEEDLINGS AND OF THE VARIETY TOP, ONE SEASON AFTER BUDDING

Stock	Variety Top				Unbudded Seedling
	Beurré Hardy	Winter Nelis	Bartlett	Beurré Bosc	
	I. Diameter of Stock and Unbudded Seedling				
Winter Nelis. .	34.1±.38	31.82±.40	31.19±.37	25.93±.32	34.76±.45
Beurré Hardy.	32.15±.32	30.00±.42	29.89±.32	24.69±.29	32.56±.42
	II. Diameter of the Variety Top				
Winter Nelis. .	25.4±.29	22.8±.33	21.9±.25	17.2±.23	
Beurré Hardy.	24.7±.24	20.9±.33	20.7±.23	16.3±.22	

The data in Table III show that in each case where the Winter Nelis seedlings constitute the rootstocks both the stock and the variety top have a greater diameter than where the Beurré Hardy seedlings were used, but only five of the cases have differences greater than three times the probable error of the difference.

The coefficient of correlation, r, has been used in an attempt to show the relationship which might exist between the size of the seedling at the time it came from the seed-bed and the size and increment of growth after planting out in the nursery. These data are shown in Table IV.

TABLE IV—COMPARISON OF SIZES AND INCREMENTS OF GROWTH (AS CROSS SECTION AREA) OF WINTER NELIS AND BEURRÉ HARDY PEAR SEEDLINGS

	Winter Nelis Seedlings		Beurré Hardy Seedlings	
	n	r	n	r
Original size and size at end of 1 year	710	.26	667	.17
Original size and area increase 1st year	710	−.022	667	−.048
Original size and diameter of new growth	710	.15	667	.08
Original size and weight of new growth	331	.19	313	−.07
Original size and size at end of 2nd year	156	.16	140	.19
Area increase 1st year and area increase 2nd year	156	.67	140	.73
Size at end of 1st year and size at end of 2nd year (Nelis and Hardy)	296	.82		
Size at end of 1st year and area increase 2nd year (Nelis and Hardy)	296	.74		

That part of the data in Table IV which deals with 2-year size or area increase during the second year are for the unbudded seedlings only. Both groups of seedlings have been combined in calculating r for size at the end of the first year and size at end of the second year and for size at end of first year and area increase the second year.

These data agree with those of Tukey and Brase (2) and of others to the effect that there is little or no relation between the size of the seedling as it comes from the seed-bed and the growth or size it may produce after being planted out. The high values of r for size at the end of 2 years, for size at the end of 1 year and area increase the second year, and for area increase the first year and area increase the second year suggest that the natural vigor of the seedling may have manifested itself immediately after transplanting from the environment of the seed-bed. However, this may not be the condition since certain seedlings may have been slower in getting a start after transplanting and this handicap may be reflected in the size and increment of the first year and even the second year.

The young trees have been grown under specially favorable conditions. They are on fertile soil, are far enough apart to prevent competition, they have always had available water and have had a long growing season. The data should be representative of what might be expected with respect to the size of young seedling pear trees 1 and 2 years after transplanting. The values obtained, an average diameter

of about 15 mm after 1 year's growth and about 30 mm after 2 years, are far in excess of any values that we have found for the size of seedlings when they have been inarched into bearing trees. This adds confirming evidence to our observations that inarching mature pear trees is probably not commercially feasible.

There seems to be little or no difference between the vigor of the two stocks as shown by the size at the end of 2 years, although the Winter Nelis seedling stock has produced a slightly larger tree in each case. The Beurré Hardy as a variety top has produced a larger tree than any of the other varieties.

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Size and Age of Budwood in Relation to Size of Yearling Citrus Scions*

By F. F. Halma, *Citrus Experiment Station, Riverside, Calif.*

THIS report is based on a portion of the data obtained in the nursery of the Rancho Sespe,[1] Ventura County, California, in connection with an investigation of the wilting of bud shoots of Valencia orange nursery trees. The data of interest here include the cross sectional trunk area of the sweet-orange seedlings (2½ years old from seed), the diameters of the apical and basal end of the bud sticks, and a record of whether the bud sticks consisted of one or two growth cycles. All nursery operations, such as culling of the stock, collecting budwood and budding, were carried out in the regular commercial manner except that in budding the buds from each stick were taken in regular order from apex to base. At the end of February, 1931, the seedling tops were cut off to force the buds into growth, and in January, 1932, just prior to planting in the orchard, the cross sectional area of the scion trunk, 45 cm above ground, was obtained.

In compiling the data given in the tables, only those trees were considered which made a full season's growth. As seen in Table I, though the diameter of bud stick from which the buds were cut, ranged from 3 to 11 mm; the average cross sectional scion trunk area was practically the same. The data in Table II include only buds from sticks 30 cm or more long, of one growth flush, in order to make a valid comparison between buds from apical and basal halves. In this case the average size of the scion of the two groups happened to be exactly the same. The bud sticks represented in Table III consisted of two distinct growth cycles; the basal or older wood presumably developed during early spring, and the apical or younger wood during the summer of the same year. Apparently this difference in age of buds had no effect on the size of the scion. A similar lack of influence was observed in several cases where the budwood was at least 1 year old.

TABLE I—Diameter of Bud Stick in Relation to Cross Section Area of Resulting 1-Year-Old Scion

Diameter of Bud Stick (Mm)	Number of Trees	Average Size of	
		Stock (Cm)	Scion (Cm)
3	49	3.35	1.19
4	49	3.25	1.16
5	57	3.16	1.17
6	49	3.59	1.15
7	48	3.54	1.19
8	44	3.19	1.15
9 to 11 inclusive	53	3.15	1.16

[1]The writer wishes to express his appreciation to Howard F. Pressey, Manager of the Rancho Sespe, and to T. A. Lombard, for their cooperation.

TABLE II—Buds From Apical and Basal Halves of Stick in Relation to Size of One-Season-Old Scion

Source of Buds	Number of Trees	Cross Section	
		Stock (Cm)	Scion (Cm)
Upper half	57	3.35	1.16
Lower half	57	3.44	1.16

TABLE III—Growth Cycle Origin of Buds in Relation to Size of One-Season-Old Scion

Source of Buds	Number of Trees	Average Size of	
		Stock (Cm)	Scion (Cm)
Late growth	85	3.32	1.18
Early growth	85	3.41	1.22

Summarizing the observations, there is no indication that the range in size and age of budwood represented in this investigation appreciably affected the growth of the yearling Valencia orange scions. Future observations will decide whether this lack of bud influence is of a permanent nature.

Crotch Angles in Young Trees

By FRANK HORSFALL, JR., *University of Missouri, Columbia, Mo.*

THE observation that larger angles in apple tree crotches are associated with increased resistance to winter injury (2) as well as the problem of crotch failure because of stress raises the question of causes behind the formation of angles varying in size. Casual attention to certain species, varieties and individuals as well as to different parts of the same tree shows that great divergence exists in this portion of the tree. Weight of the first crops of fruit may increase the angle size but, even with this, some old trees have limbs which grow at angles of 20 degrees or less.

The growth of nursery trees when topped is characterized the second year by narrow crotches on limbs close to the topping cut. The width of these angles increases with increasing distance from the upper end of the trunk (3). The greater the distance from the top, the smaller is the average limb diameter. This limb diameter decrease, along with the normal increase of trunk diameter toward the base, brings about a decided gain in the ratio of trunk to limb size at the point of junction. A large ratio of trunk to limb diameter appears to be positively correlated in some way with wide crotches. Short limbs were observed by Blake (1) to form wide crotches.

In considering angle width it is well to call attention to the system of producing crown budded trees as a cutting back process because of the removal of the above ground parts of the stock. The comparison of orchards grown from budded trees with those propagated other ways gives clear evidence that few if any lastingly harmful effects follow the cutting back treatment.

A study of several thousand 1-year-old Kieffer pears, budded on ussuriensis rootstocks, brought out in keeping with the crotch sizes in other cut backs (4) that the limbs made wide angles with the trunks. A great majority of these trees had strong leaders with nearly every one of the crotch angles close to the general average of 64 degrees. A few interjacent trees making relatively weaker growth had no well defined leaders, but the main stems had divided into a number of limbs about equal in size and length. The lower crotches of these smaller trees were wide but the uppermost limbs had formed narrow crotches. Here, as with many other kinds of trees, the wide crotch is associated with large ratio of trunk to limb diameters. A limb making vigorous diametric and linear growth the first year may form a wide angle if the trunk to limb ratio remains large. The combination of the excurrent type of trunk with wide crotches is readily seen in certain conifers such as the white pine and the fir.

Tukey and Brase (5) found that the least vigorous grafts have roots which develop at an acute angle with the vertical, whereas the most vigorous grafts seemed to have a more spreading habit of root growth.

In cut back Jonathans it was noticed that the young scaffold limbs

start out in the axils of the leaves and grow almost vertically upward for about an inch or a little more. Something then occurs in the subsequent growth to turn the longitudinal limb axis from the vertical toward the horizontal position for at the end of the first growing season these same limbs form large crotch angles, sometimes close to 90 degrees.

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The Circumferential Variability of Five Varieties of Apple Trees on Seedling and Scion Roots

By F. S. Lagassé, *Experiment Station, Newark, Del.*

IN 1931 results were published (1) comparing the variability of five varieties of apple trees growing on their own and seedling roots before and after three growing seasons. This report is a consideration of the circumferential variability existent among a portion of the same trees at the beginning and conclusion of five growing seasons under orchard conditions. Orchardists and horticulturists have been unable from casual observation to distinguish between them as growing under orchard conditions.

Materials

A detailed description of the materials and methods of propagation and orchard management was presented in the 1931 report (1). The effect of a nearby woodlot (50 feet from the nearest row of Yellow Transparents) has become evident during the last 2 years and accounts to a large extent for the unusually high C.V. of this group of trees. No trees considered in this report have been pruned, excepting a top pruning given at the time of transplanting from the nursery to the orchard, the purpose being to eliminate pruning as one of the possible factors contributing to variability. Exception to the above statement is made in the case of the Yellow Transparent, for the terminal growths of some trees were eaten by a stray cow in the summer of 1931. Caterpillar damage also occurred to a few trees in the late summer of 1932.

Results

Table I shows that in the five varieties studied, Yellow Transparent, Stayman, Delicious, Grimes, and Rome, at the start of the study in 1929 the mean circumference of the seedling-rooted trees was significantly greater than that of scion-rooted trees in all but Rome. This exception was as previously mentioned (1) due to the necessity of having to use a medium-sized grade of seedling-rooted nursery tree. After five growing seasons the mean circumference of the seedling-rooted Stayman, Delicious, and Rome trees is significantly greater than that of the scion-rooted trees. The seedling-rooted Grimes are still greater in mean circumference than the scion-rooted trees of this variety but not significantly so, whereas the scion-rooted Yellow Transparents have a greater mean circumference than the seedling rooted trees, but not of significant proportions.

As the trend of four of the five varieties is the same relative to circumferential increase of the scion and seedling-rooted trees, a general conception of the average response on each type of root is presented in Fig. 1. The average yearly circumference increments of scion-rooted and seedling-rooted trees of the five varieties are plotted

TABLE I—THE MEAN AND COEFFICIENT OF VARIABILITY OF THE CIRCUMFERENCE OF UNPRUNED TREES IN THE SPRING OF 1929 AND FALL OF 1933

Variety	Type of Roots	Number of Trees	Trunk Circumference (Cm) Mean 1929	Mean 1933	C.V. 1929	C.V. 1933	Diff. and P.E.D. 1929–1933
Yellow Transparent	Scion	30	3.2±.069	13.9±.607	17.6±1.53	35.5±3.093	17.9±3.45
	Seedling	28	3.9±.090	12.3±.549	18.4±1.66	35.1±3.161	16.7±3.57
		Diff. and P.E.D.	.7±.113	*1.6±.819**	*.8±2.26*	*.4±4.423*	
Stayman	Scion	29	3.7±.083	17.0±.470	18.0±1.59	22.0±1.951	*4.0±2.52*
	Seedling	27	4.0±.041	19.1±.484	8.0±0.73	19.5±1.793	11.5±1.94
		Diff. and P.E.D.	0.3±.093	2.1±.675	10.0±1.75	*2.5±2.650*	
Delicious	Scion	23	3.3±.070	14.5±.573	15.4±1.53	28.1±2.798	12.7±3.19
	Seedling	30	4.2±.031	17.7±.380	6.1±0.53	17.5±1.521	11.4±1.61
		Diff. and P.E.D.	0.9±.077	3.2±.688	9.3±1.62	10.6±3.184	
Grimes	Scion	59	3.3±.060	18.9±.381	20.6±1.28	22.9±1.424	*2.3±1.92*
	Seedling	52	4.8±.057	20.1±.388	12.7±0.84	20.7±1.367	8.0±1.60
		Diff. and P.E.D.	1.5±.083	*1.2±.544*	7.9±1.53	*2.2±1.974*	
Rome	Scion	78	4.0±.055	13.0±.196	18.6±0.99	19.8±1.071	*1.2±1.46*
	Seedling	80	3.7±.029	14.0±.229	10.5±0.56	21.7±1.157	11.2±1.29
		Diff. and P.E.D.	0.3±.062	1.0±.301	8.1±1.14	*1.9±1.577*	

*Italics indicates difference is not significant.

for five seasons' growth. The seedling-rooted trees were somewhat larger at the start of the study and on the average have remained so through five growing seasons. On an actual amount basis, the scion-rooted have closely approximated the seedling-rooted trees, as is apparent from the parallelism of the lines of the graph.

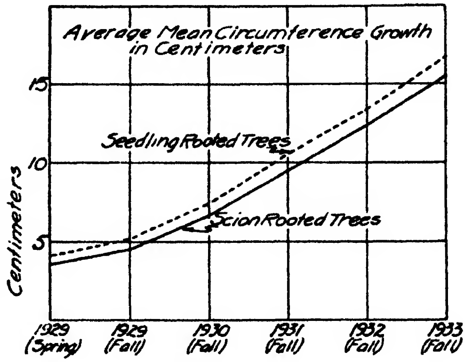

FIG. 1. Average mean circumference growth.

If the average annual percentage increase in circumference of these scion and seedling roots is considered with relation to the original circumference, however, the scion-rooted trees (Fig. 2) have done somewhat better than those of the same varieties on seedling roots.

Considering next the coefficients of variability in circumference of the scion and seedling-rooted trees Table I shows the seedling-rooted trees, with the exception of the Yellow Transparent, had very much lower variability at the start than the scion-rooted trees. The scion-rooted Yellow Transparents had an insignificantly lower coefficient of variability, in the spring of 1929.

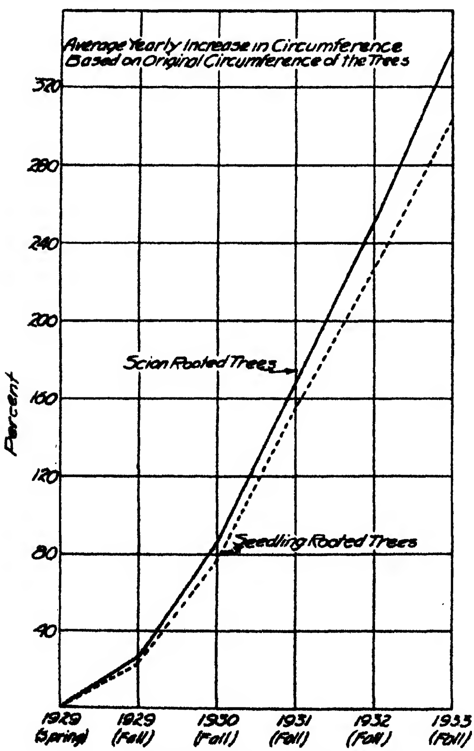

FIG. 2. Average yearly percentage increase in circumference based on original circumference of trees.

As previously mentioned (1), it is believed that the coefficients of variability of the scion-rooted trees could be considerably reduced at the start, were the study to be repeated, by selecting from a larger population, as undoubtedly occurred in the case of the seedling-rooted trees used.

Table I shows that by 1933, the coefficients of variability of both the scion- and seedling-rooted Yellow Transparent trees

are about double what they were in the spring of 1929, but the difference between them is still insignificant.

The scion-rooted Stayman have remained very close to their 1929 coefficient of variability, the difference being insignificant. The seedling-rooted Stayman in contrast have made a very significant increase from 8.0 ± .73 to 19.5 ± 1.793. As a result the present difference between the coefficients of variability of the trees on the two different types of roots is not significant.

Delicious did not produce as many good scion-rooted trees in the nursery row (2) and this undoubtedly accounts to a great extent for the considerable and significant increase in variability noted in the scion-rooted trees of this variety. The seedling-rooted Delicious have also varied significantly more during the past 5 years.

The scion-rooted Grimes have changed but slightly and not significantly in their circumferential coefficient of variability. The seedling-rooted Grimes have in contrast increased significantly, from 12.7 ± .84 to 20.7 ± 1.367. The difference between the coefficients of variability of the scion- and seedling-rooted Grimes in 1933 is not significant.

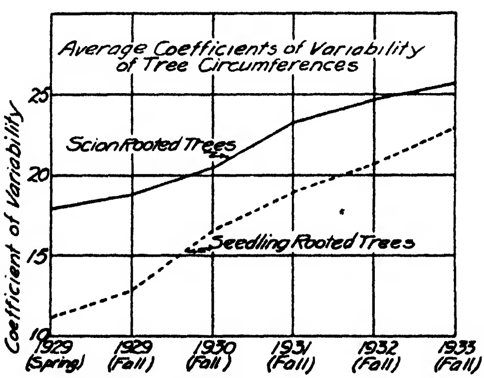

FIG. 3. Average coefficients of variability.

The scion-rooted Rome trees in 1933 are but slightly and insignificantly higher with respect to their circumference coefficient of variability than in 1929, while the seedling-rooted Rome group have increased significantly from 10.5± .56 to 21.7 ± 1.157 and now have a greater coefficient of variability than the scion-rooted group. The difference, however, is insignificant.

The average yearly circumference coefficients of variability (1929–1933) of the five varieties on the two types of roots are presented in Fig. 3. At the start of this study, the scion-rooted had a higher coefficient of variability than the seedling-rooted trees, and this condition existed during each of the 5 years. Trees on both types of roots increased yearly in their circumferential C.V. but the seedling-rooted trees increased more in this respect than those on scion roots.

Graphs of the yearly (1929–1933) circumferential C.V. of each variety (not here presented) show that the scion-rooted Yellow Transparent and Delicious have increased a little more sharply than the seedling-rooted trees of these varieties. The Stayman, Grimes, and Rome varieties on scion roots have, on the other hand, remained much closer to their original C.V. than the seedling-rooted trees.

Conclusions

Scion-rooted trees of several varieties have been found to compare favorably in growth as measured by their annual increase in circumference with trees on seedling roots.

The scion-rooted trees used had higher C.V.'s at the start of the study than the seedling-rooted trees. After five seasons of growth under orchard conditions, they still have higher C.V.'s with the exception of the Rome, but the encouraging thing is that the scion-rooted trees in general have not increased as much in their variability as the same varieties on seedling roots. The C.V.'s of the seedling-rooted trees of all varieties increased significantly (1929–1933) Table I, while the increases in C.V.'s occurring with scion-rooted trees were not significant in Stayman, Grimes, and Rome. This latter fact seems very important. Thus, if it is possible by selecting scion-rooted trees from sufficiently large populations to reduce their circumferential coefficients of variability to that of the average tree on seedling roots, we would have available a type of tree which might prove to be less variable and thus more desirable, at least from an experimental viewpoint, than trees on seedling roots.

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Propagation Experiments With Avocado, Mango, and Papaya

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DURING the past year several different investigations relative to the propagation of the avocado, mango and papaya have been conducted in Florida. In this preliminary report, the results of a few of the different experiments will be described.

Germination media:—Avocado seeds of Gottfried (Mex.) during the summer season, and Shooter (Mex.) during the fall season; and Apple Mango seeds during the summer season, were germinated in 16 media contained in 4 x 18 x 24 cypress flats with drainage provided in the bottom. The eight basic materials and eight mixtures of these, in equal proportions in each case, tested were: 10-mesh charcoal, 6-mesh charcoal, pine sawdust, cypress sawdust, sand, fine sandy loam, carex peat, sphagnum peat, sand plus loam, carex peat plus sand, sphagnum peat plus sand, carex peat plus loam, sand plus coarse charcoal, loam plus coarse charcoal, cypress sawdust plus coarse charcoal, and carex peat plus sand plus coarse charcoal.

During the rainy summer season, with relatively high temperature and an excess of moisture without watering, 10-mesh charcoal, and the mixture of carex peat plus sand plus charcoal proved most rapid, but for the drier, cooler fall season, when watering was necessary, the mixture of cypress sawdust plus charcoal was added to the list. During the rainy season the two charcoal media, sphagnum peat, sand plus charcoal, cypress sawdust plus charcoal, and carex peat plus sand plus charcoal gave the highest percentages of germination at the end of 6 to 7 weeks, but during the drier season the first three were displaced by carex peat plus sand, and sphagnum peat plus sand.

Seedlings were in the best condition, on the basis of stem diameter, height, leaf size, root length, branching, and soundness, and general thriftiness of the whole plant, at the end of the experiment during the rainy season in sphagnum peat; and cypress sawdust plus charcoal, but these were replaced by sphagnum peat plus sand, and carex peat plus sand plus charcoal for the drier season.

The use of 10-mesh charcoal accelerates germination during both seasons and is apparently otherwise beneficial during wet weather. However, sand may be substituted in some mixtures to obtain highest percentage of germination and best development during the drier season. Sphagnum peat causes less decay of seeds and roots than carex peat.

The results for Apple mango seeds, though not as clear as those for the avocado seeds, show conclusively that 15 other media tried are much superior to Orlando fine sandy loam.

The experiment will be repeated during the winter season, and will be continued next season with a smaller number of media which appear superior. Some of the poorer media, such as fine sandy loam,

which appeared inferior under the conditions of these experiments, will be eliminated.

Germination of immature avocado seeds:—These experiments have for their purpose to determine how early in their development avocado seeds can be sprouted and at what stage such immature seeds can be used for commercial propagation purposes. This subject also has important bearing on breeding operations; since the avocado is notorious for the number of fruits shed. Sprouting immature seeds may save valuable breeding material.

A small percentage of very immature seeds, Collins (Guat.), Winslowson (Guat. x W. I.), Mayapan (Guat.), gathered during the May and June drop of the past season sprouted, and more than 95 per cent of the seeds from fruits blown from the trees at the Orlando station during the hurricane of September 3, 1933, have germinated and are producing excellent plants. Even the immature seeds from the late maturing variety, Collins (Guat.) produced seedlings. The seed maturity ranged from 35 per cent for Collins (Guat.) to 80 per cent for Mayapan (Guat.) and Perfecto (Guat.) on the basis of comparison of weight of immature seed with weight of previous season's mature seed.

Sprouting fractional embryos:—When the two avocado cotyledons are broken apart, a fraction of the meristematic tissue will remain attached to each. In some types of seeds these fractions are approximately equal, in others this generally does not hold true. The explanation in terms of physical laws has not as yet been worked out. However, no matter how small the fraction of meristematic tissue, it usually sprouts under favorable conditions. These halves may in turn be cut into two approximately equal parts each with approximately a quarter of the meristematic tissue and these usually sprout. The process might conceivably be extended even farther, but the percentage sprouting from eighth embryos is apparently markedly delayed or reduced as compared with quarter embryos, from causes not definitely determined.

Average measurements, at intervals from April 8 to October 17, of stem diameter and height of Collins (Guat.) plants, secured from whole, half and quarter embryos, show that plants from fractional embryos lag behind those from whole embryos. Although in this case the plants from fractions did not reach the same stem diameter and total height as the controls from the whole embryos, a large percentage did reach a trunk diameter of 6 mm. In root development the plants apparently were equal to the controls. Splitting the embryo into fractions may be compared to the pruning process, which has a dwarfing effect. This might account, in part, for the lag of the above-ground portion of the trees from fractional embryos. This subject must, however, be considered in the light of the size of the avocado seeds. Plants from small seeds as a rule are smaller at a given time than those from larger seeds. Therefore, plants from fractional embryos secured from small seeds might not reach the necessary ¼-inch stem diameter wanted for ease in budding in the desired length of time.

These results with the sprouting of fractional embryos, used in connection with the method of budding avocado embryos on small or large trees (2) in genetic studies, makes it possible to overcome the objection to the method, that in case of failure in securing union the variate would be lost.

Sprouting mango embryos may be cut into fractions which will produce multiple sprouts when planted. With polyembryonic varieties this would apparently have no practical value, but may be worthy of consideration as a means of increasing the number of progeny from monoembryonic seeds for use in plant breeding and phytopathological experiments where it is necessary to test sexual offspring in different locations and with various inoculations.

Avocado fractional embryo graftage:[1]—As announced in a previous paper (3), this work has been extended to include the testing of variations of the general method and also the influence of kind and condition of graftwood, varietal differences, and propagation media. It is of interest to note a method which has been brought to our attention since the publication of our preliminary announcement (3). In this case the sprouting embryo is used as a bud (2) and the object and types of grafting are the reverse of those which we set forth. The method used in breeding work to shorten the time required to determine the value of seedlings, "consists in using the newly started embryo of a sprouting seed as a bud either in nursery stock or in the limb of a large tree...one of the two large cotyledons is carefully removed with a sharp knife without disturbing the developing plantlet. A sharp cut is made beginning at the base of the tiny shoot and extending through to the root tip. The other half of the seed is sometimes cut away, leaving a small wedge-shaped portion to assist in forcing the rootlet into the incision, or it may be left on entirely" (2).

In general the method of fractional embryo graftage consists of wedge grafting a cion, 2 to 5 inches in length, into the meristematic tissue of the fractional embryo either vertically from the top or at an angle of about 45 degrees, into the center of the embryo where it unites with the cotyledon. The fractional embryo may be used in at least three developmental stages, (a) dormant, (b) just sprouting, and (c) sprouted still farther. In a variation of (a) and (b) above, the whole embryo may first be sprouted and then split lengthwise into approximately equal parts including the root or roots.

Avocado seeds are of various shapes, from long, narrow, pointed to approximately spherical and flattened. It will facilitate matters to describe the insertion of the graft in the latter case, where a cotyledon

[1]After this paper was presented at the Boston meeting of the Society, the authors' attention was drawn to other somewhat similar work in which whole sprouted embryos were used as contrasted with the dormant or sprouting fractional embryos used in our work. Cornu grafted tender cions on the "collar a little below the attachment of the cotyledons" in chestnut, walnut, Pavia, and rosaceous stone fruits. (Jour. Soc. Nat. Hort. France, 3 ser. 17: 505–510. 1895; *ibid.* III 20, 90. 1898; Baltet, L'Art de Greffer. Paris, 264. 1902. Rockens inserted tender grafts of *Clianthus* in the split plumule of *Colutea* plants a few days old. (Rev. de. l'Hort. belge et étrangère. 31: 7–9. 1905.

represents an approximate hemisphere. First a section shaped like an acute pyramid, with its point in the center of the fractional part of meristematic tissue, is removed. In performing the operation, two cuts, from ¼ to ⅛ inch apart are started at the edge of the cotyledon at the plumule end, or 45 degrees in either direction on the edge. The cuts are slanted inward at an angle of approximately 25 degrees on the flat side of the cotyledon toward the center of the embryo, and also toward each other, at an angle of approximately 45 degrees, on the curved side of the cotyledon. When these cuts are carried to their intersection the desired section may be removed. The cion is prepared to fit into the opening. Beginning at the base of the lower bud with even strokes of the knife, a three-sided pointed wedge is formed. The uncut curved surface is placed on the outside and the pointed wedge toward the center of the opening in the fractional embryo. The pointed wedge is then inserted firmly but not too tightly with the point in the center of the fractional embryo, for care must be exercised not to crush the cells. No tying is needed. Any exposed cut surfaces should then be covered with 45 to 49 degree C melting point paraffin (1). Care must be exercised not to force the paraffin between the cion graft and the meristematic tissue of the fractional embryo. The opening on the curved side of the cotyledon is filled with paraffin, the graft being held at a slight angle with the cion uppermost.

Grafts are planted either sideways or flat side up at an angle of 45 degrees C in flats 5 inches high. The types of propagation media of most value for this purpose have not been determined experimentally. The grafts can be planted in 6 x 6 x 12 cypress boxes or nursery row as soon as sprouts appear.

There is varietal difference with respect to ease of graft union. The effect of race, Guatamalan, Mexican, and West Indian, of both stock and cion on the results are being investigated. The kind and condition of graftwood as well as the seasonal changes have a marked effect on the response.

Mango sprouting embryo graftage:—Although the costly inarching method is still practiced, most nurserymen now use either the shield budding or whip grafting methods in the propagation of the mango. However, success with the last two have been achieved only by few. During the past 2 years limited experiments have been tried with grafting sprouting mango embryos for the dormant mango embryo is not far enough advanced to make graftage practicable.

The mango sprouting embryo is very brittle and the operation is delicate. The plumule is cut off near the base of the cotyledons, a slit is made down the center between the cotyledons, and the wedge shaped cion, 2 to 4 inches long, is inserted at a slight angle and tied with a rubber band not too tightly since the tissues are very succulent and easily injured. The exposed cut surfaces are covered with 46 to 49 degrees C melting point paraffin.

The grafts are planted at an angle in a sprouting medium contained in flats 5 inches high. The grafts sprout as a rule within 3 weeks. These should not be transplanted until the new growth has hardened.

To save the greatest percentage of sprouted grafts it may be necessary to sprout them in individual pots. The percentage of successes for various lots ranged from 0 to 80 per cent. Further attempts will include the study of the effect of kind and condition of graftwood on the response.

Papaya cuttage experiments:—Experiments in propagation of papaya, and also with avocado and mango, by cuttage and layering have been a disappointment so far. Extensive cuttage experiments with papaya (more than 300 cuttings), and avocado (more than 2000 cuttings) under ordinary slat shed propagation conditions have proved a total failure. In both cases callusing has been accomplished, but no root formation was secured. In the case of the papaya much decay was present unless the cuttings were covered with bell-jars to increase atmospheric humidity. In further experiments the influence of bottom heat on the response will be determined.

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Notes on Pecan Filling and Maturity

By A. H. Finch,[1] *University of Arizona, Tucson, Ariz.*

THE failure of pecan nuts to fill well has been a source of loss to growers in the older pecan districts for many years. With the coming into production of groves in the irrigated southwest it is evident that a problem of filling exists here also. In addition, nuts of some varieties tend to germinate on the tree shortly before harvest time and are thus rendered unmarketable. This condition has been termed "pre-harvest germination." Other problems of maturity, including one of late ripening of nuts, have arisen in this region of long growing seasons and high summer and fall temperatures.

Work previously reported (2) indicated (a) that starches, sugars, and possibly other forms of carbohydrates are present in shoots and cluster stems near the nuts during the summer; and (b) that sugars are present in the liquid contained within the seed coat prior to the formation of the "meat." These data were thought to suggest that the formation of carbohydrates preceded the formation of fats and that filling would be dependent upon the presence of carbohydrates and their subsequent conversion and storage in the kernel as fats. The solution to the problem of filling then seemed to demand a control over carbohydrate movement and storage. The best filling would likely accompany a considerable accumulation and storage of carbohydrates in the tree.

In contemplating the problem of pre-harvest germination, it was believed that the factors underlying germination of the nuts on the tree were no different than those providing for germination of seeds in general, namely, moisture, aeration, favorable temperature and viability of the seed. Of these, the amount of moisture available to the nuts seemed of most practical importance, particularly when it was noted that the shuck surrounding the nut contained considerable moisture during late summer. The solution of the problem of pre-harvest germination seemed to call for reduced moisture in the shuck and its separation from the shell.

Previous work (1) indicated that carbohydrate accumulation is relatively greater in weak than in strong pecan shoots. Later it was noted that leaves on poorly growing trees became yellow, brittle, and dry in the late summer whereas those on strongly growing trees did not reach a comparable maturity until late in the fall. Shucks on weakly growing trees seemed likewise to mature early. It was then reasoned that if, in the pecan, carbohydrate accumulation and drying of the shucks are both related to a condition of vegetativeness of the tree then filling and pre-harvest germination are possibly related

[1]The writer is indebted to Mr. J. F. Breazeale, Dr. R. A. Greene and Mr. A. D. Ayres, of the Agricultural Chemistry Department, University of Arizona, for making the soil nitrate, wilting point, and moisture equivalent determinations and nitrogen analysis of plant tissue reported herein.

problems, and both might be influenced by the vegetativeness of the tree during late summer.

During the summer of 1932, some small limbs of pecan trees in the Yuma Valley of Arizona were girdled and others defoliated in an effort to produce differences in vegetative growth, carbohydrate accumulation and maturity. At harvest time records of filling and germination were obtained on nuts produced on these limbs, on nuts from weak and strong shoots of untreated trees and on nuts from trees somewhat unlike vegetatively.

The girdling and defoliating treatments did not produce consistent results. Filling was not greatly different with nuts on weak and strong shoots of the same tree but germination was greater on the latter. The least vegetative trees had the best filled nuts, these ripened earlier, and fewer germinated.

Such studies were extended in 1933, using chiefly the Burkett variety. On September 18, some trees were girdled at the trunk. During September, cultural treatments designed to depress soil nitrates were initiated. At this time also, trees varying widely in degree of vegetativeness were selected throughout the Yuma Valley. Selections were made on the basis of vegetativeness (greenness of foliage and shoots) without regard to character of soil, culture, depth of water table, or irrigation schedule. However, at 5-day intervals from September 30 to November 1 (the period of filling and germination) soil moisture and nitrate content were determined on samples taken at each location to a depth of 10 feet or to the water table. Occasionally, during this period nuts were picked and stored in damp sphagnum moss. During this time, also, without taking the nut from the tree, a portion of the shuck was removed from about 1,000 nuts on highly vegetative trees leaving the distal end of the nut exposed.

Of the nuts picked and placed in damp sphagnum moss on September 17, none had germinated at the end of 20 days. Of those picked on September 27, 20 per cent germinated. Of those picked on October 7, and subsequent dates, never less than 92 per cent germinated. Clearly pecan nuts may be viable for some time prior to harvest. All that is necessary for the pre-harvest germination of the nuts are the usual requirements for germination of seeds.

Nuts from which the tip of the shuck was removed in September were harvested November 1. Five per cent of these had germinated compared to 40 per cent for untreated nuts in the same clusters. Removing a portion of the shuck seemed to provide for drying out of the nut.

When harvested, nuts on the girdled trees were reasonably well filled and 18 per cent had germinated. Check trees growing with a Hubam cover crop disked on September 20, were less well filled, matured later, and had 38 per cent germinated. Trees with a Sesbania cover crop remained green late into November. Nuts from these were harvested on November 8, but were not well matured at that time. Thirty per cent had germinated.

A close correlation was found betwen vegetativeness of the trees and filling, maturity and germination of the nuts (Fig. 1). Trees

selected as being weakly or poorly vegetative had ceased growth during mid-summer. By October 15, leaves and petioles were slightly yellowish and the bark a reddish yellow. Nuts on these trees were ripe and harvested October 21. They were well filled, having plump, white, and oily kernels. Shucks separated readily from the shell and none had germinated. Trees selected as being highly vegetative continued growing into the late summer; leaves, petioles and bark were green thruout the fall. Nuts from them were harvested November 7, at which time the shells were not well colored, shucks separated with difficulty, the meat present was of poor quality. Forty-one per cent germinated. Between these two extremes of vegetativeness were trees having nuts of intermediate filling and maturity. Germination tended to be intermediate but could not be accurately determined because the amount of germination is influenced by the relative picking date. The longer nuts remain on the tree, the greater is the proportion that germinates.

In two of the orchards upon which soil moisture and nitrate studies were made the moisture content of the first 2 feet was below the wilting point thruout the period sampled. At lower depths it was above the wilting point and above the moisture equivalent. In other orchards the moisture was above the wilting point at all depths and above moisture equivalent not only at the lower depths, but generally in the surface 2 feet, as well. None of the trees showed any wilting, marginal burning or dropping of leaves—conditions believed to be associated with deficient moisture.

Of the trees growing with available soil moisture at all levels, those in soils having most nitrates were the greenest and bore poorly filled nuts which were late in maturing. Of trees with moisture content below the wilting point in the surface soil there was no relation between soil nitrates and greenness of the trees. In this case nitrates which were most abundant in the surface 2 feet of soil, may not have been available to the tree. While the influence of soil nitrates on the greenness of the tree was thus modified by the availability of nitrogen or other factors, the correlation between the character of nuts borne and the vegetativeness or succulence of the tree remained constant.

The amount of soil nitrate appeared to be influenced by cultural practices. Straw disked into the soil in a young, non-fruiting grove on September 10, caused some reduction of soil nitrates but did not influence greatly the appearance of the trees. Alfalfa plots in the same orchard showed reduced soil nitrates. Trees in these plots took on autumn colorations and leaves fell before frost.

On October 29, samples consisting of shucks, nuts and shucks, and tips of non-fruiting shoots were taken from the following:

1. Poorly vegetative trees. Nuts were well filled (Fig. 1, left), matured early and .73 per cent germinated. Soil moisture here was approximately 9 per cent above the wilting point. Nitrates were low.

2. Moderately vegetative trees. Nuts were moderately well filled (Fig. 1, center), matured moderately early and 39 per cent germinated. Soil moisture here was approximately 12 per cent above the wilting point. Nitrates were intermediate.

3. Highly vegetative trees. Nuts were poorly filled (Fig. 1, right), matured late and 30 per cent germinated. Soil moisture was about 10 per cent above the wilting point. Nitrates were high.

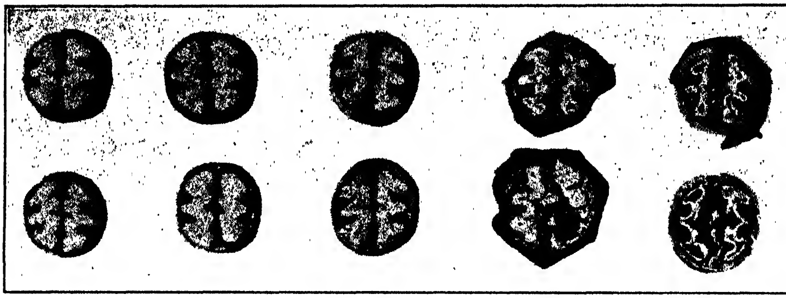

FIG. 1. Filling of nuts in relation to vegetativeness of the tree. Collected October 21, 1933, Yuma, Arizona. Left to right: poorly to highly vegetative trees. Note differences of filling, coloring of shell and adherence of shuck.

The samples were placed at once in weighed air-tight containers. These were taken to the laboratory, weighed, and dried at 100 degrees C to approximately constant weight for moisture content. The same samples were later analyzed for nitrogen content, using the standard Kjeldahl method.

TABLE I—MOISTURE AND NITROGEN IN PECAN TISSUE IN RELATION TO VEGETATIVENESS OF THE TREE AND FILLING OF THE NUTS

	Shucks Only		Nuts and Shucks		Shoots	
	Moisture (Per cent)	Nitrogen (Per cent)	Moisture (Per cent)	Nitrogen (Per cent)	Moisture (Per cent)	Nitrogen (Per cent)
Poorly vegetative tree. Well filled nuts	79.15	.79	57.75	1.32	51.25	.74
Medium vegetative tree. Medium filled nuts	83.5	1.18	64.37	1.21	53.15	.70
Highly vegetative tree. Poorly filled nuts	85.8	1.93	71.47	1.43	55.35	.73

Filling, date of maturity of the nuts, and pre-harvest germination seem clearly related to the condition of vegetativeness or greenness of the tree during September and October. This in turn seems to be most dependent upon available nitrogen. Moisture content of the shuck may be reduced not by reducing soil moisture but by cultural practices to make trees less vegetative.

The present data suggest that a solution of the problem of filling and of what now appear to be related problems of maturity and quality of the nuts, lies in making the trees less vegetative in the late

summer and fall. From a cultural standpoint it appears desirable to obtain yellowish or autumnally colored leaves in early fall. It is thought that in so doing, physiological changes will occur in the tree favorably influencing the storage of fats and the early maturity of the nut and shuck. Important among these may be the accumulation of carbohydrates.

The practical accomplishment of this end may be complicated in that, as some data and observations have indicated, the best blossoming, setting of young nuts and sizing of nuts during early summer may accompany a relatively high degree of vegetativeness during that period. Accordingly, the best fruiting of pecan trees may involve a change from a highly vegetative condition in the spring to a poorly vegetative one in late summer. Perhaps this means that a relatively high nitrogen composition is desirable in the spring and early summer and a relatively high carbohydrate composition desirable in late summer and fall. In attaining any such seasonal change in composition the role of soil nitrogen and of nitrogen and carbohydrate reserves within the tree will likely be found important.

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Leaf Area and Shoot Growth in Relation to Size and Filling of Filberts

By C. E. Schuster, *U. S. Dept. of Agriculture, Corvallis, Ore.*

INVESTIGATIONS on the effect of leaf areas on the development of fruits have for the most part been concerned with fruits in which pollination is quickly followed by fertilization. The resulting early growth of the fruit more or less coincides with the vegetative growth of the tree. The present report covers work done on the Barcelona filbert, the most widely planted variety in the Pacific Northwest. The filbert has certain growth characteristics of the fruit not commonly found in other horticultural species.

Pollination of the female flowers of the filbert usually occurs in January or February. Some weeks after this the vegetative growth of the tree begins. From the bud containing the pistils, a shoot pushes out, at the tip of which is carried the inner part of the bud and the encysted pollen nuclei. At about the time this shoot growth is completed, the shell of the nut enlarges rapidly and is filled with pith and a very small amount of undifferentiated tissue that later forms the embryo. Some time in June or July fertilization takes place and the kernel then develops. A normal sized kernel fills the shell when mature but undried. Some of the shells will be empty and others will contain kernels that vary in size from a mere strip of tissue to those of normal size.

In the present work, the leaf area was adjusted by removing excess leaves so that there would be a certain number of average-sized leaves per nut for any shoot. The average size of the leaves was approximately 35 square cm. At the same time the leaf area was reduced, part of the shoots were girdled by removing a narrow strip of bark, after which the exposed parts were waxed over. Other shoots had a similar adjustment of foliage, but were not girdled.

Artificially fixing this stated area of leaf surface per filbert occurred before fertilization of the egg and while the shell was still enlarging. The ideal time would be as soon as the number of leaves on a shoot could be known, but at that time it is impossible to determine whether a flower bud will form a cluster or how many nuts there will be to a cluster. So it is necessary to delay the work until nearer the time of fertilization.

In recording results, a nut was classed as a blank if it was apparent that no growth of the kernel had ever resulted after fetilization or possibly no fertilization had occurred. While the shell developed to approximately its normal size, something prevented fertilization or subsequent growth of the kernel.

The percentage of totally blank or empty shells varied little with the leaf area. Blank nuts were as apt to occur in groups with large leaf areas as in those with small leaf areas. Apparently the fertilization would proceed or fail regardless of the leaf area subtending the flowers. Although this leaf area had been functioning for some time

and seemed to have no effect on fertilization, there was a marked influence on the subsequent filling or growth of the kernel and to a much less extent on the shells of these filled nuts.

A filled nut was one in which the kernel made more or less growth. The kernel might fill 10 per cent or less of the interior of the shell and in packing houses would be taken out as a blank nut, yet in this work it would be grouped among the filled nuts.

A normal nut was one in which the kernel approximately filled the interior to the extent usual for the variety. A normal nut could be large or small. It was difficult to actually differentiate between those that were fully developed and those that might lack 10 to 15 per cent of full development so all above ¾ normal size were classed as normal. These would be accepted as good nuts in the trade. The groupings were arbitrary and dependent on the judgment of one man.

The data in Table I are from the first year's work in which the defoliation and girdling was probably delayed too long on the Barcelona.

TABLE I—Relation of Amount of Foliage to Weight of Barcelona Filberts, 1931

Leaf Area	Average Weight of Nut (Gms)	
	Girdled	Not Girdled
1 leaf per nut	1.91	2.14
5 leaves per nut	2.56	2.59
10 leaves per nut	2.92	2.79
20 leaves per nut	3.01	3.02

Data from the Merveille de Bolwyller, a variety that blooms much later and in which the fertilization occurs some time after that of the Barcelona, showed a much wider variation in the size of the nuts. It was noted that much of the difference in weight and size was due to defective kernels that occurred more frequently in those groups with small leaf areas.

During the following season the work of girdling and determining the leaf area on the Barcelona was started before it was possible to fully decide how many individuals to a cluster would survive. Later, adjustments were made. Results are summarized in Table II.

TABLE II—Relation of Leaf Area to Percentage of Normal Nuts and to Weight of Nuts in Barcelona Filberts, 1932

Leaf Area	Normal Nuts		Average Weight of Normal Nuts (Gms)		Average Weight of All Nuts with Kernel* (Gms)	
	Girdled	Not Girdled	Girdled	Not Girdled	Girdled	Not Girdled
½ leaf to nut	24.37	82.09	1.23	2.39	.746	2.313
1 leaf to nut	32.40	80.0	1.83	2.43	1.251	2.341
5 leaves to nut	76.78	86.19	2.45	2.67	2.430	2.616
10 leaves to nut	84.37	90.96	2.78	2.84	2.798	2.812

*This includes nuts ¼, ½, ¾, and normally filled.

The significant fact is the percentage of normal nuts under the different conditions and the close correlation of leaf area with the percentage of normal nuts on the girdled shoots. As would be expected, the greatest variation was with the kernels but there was a corresponding, though smaller, variation in weight of the shell. In one group the average weight of shells for those with a kernel less than one-fourth normal size was .27 grams while for those with normal kernels it was .64 grams. The same relative weights held in all groups. Apparently the failure of the kernel to develop properly was reflected to a limited extent in the decreased weight of the shell.

Where the nuts were totally dependent on the leaf area subtending them, as on the girdled shoots, the variation in weight follows closely the difference in leaf area and is considerable. On the non-girdled branches the normal nuts are more numerous, particularly in the groups of small leaf area, and show much less variation in weight of these normal nuts.

The smaller variation of the non-girdled material has similarly been reflected in a lesser variation in the shell as compared to the kernel. Apparently enough translocation of plant food occurred to partly compensate for the lack of leaf surface in certain groups so that the shells were more nearly the same as with the normal nuts.

The non-girdled material would approximate natural conditions except that the small leaves and extra large leaves had been removed so that an average leaf surface of about 35 square cm per leaf could be had. Five leaves to a nut would be approximately 175 square cm to a nut.

Under natural field conditions, leaves of all sizes would subtend a cluster of nuts. To determine the effect of actual, natural leaf area on the size of nuts the leaf area was measured by matching the area of each leaf with known areas of celluloid and the overrun calculated, Table III.

TABLE III—RELATION OF AREA OF FOLIAGE ON TYPICAL BRANCHES TO PER CENT NORMAL NUTS AND AVERAGE WEIGHT OF NUTS, BARCELONA FILBERTS

Leaf Area in (Sq. Cm)	Normal Nuts (Per cent)	Average Weight of Normal Nuts (Gms)
0–50	69.5	3.27
51–100	68.5	3.08
101–150	77.2	3.12
151–200	82.0	3.41
201–250	70.8	3.31
251–300	83.3	3.43
301–350	100.0	3.40
351–400	100.0	3.37
401–450	100.0	3.42

The group of 51 to 200 square cm of leaf area would be comparable to five leaves to a nut. It will be noted that the variation is quite similar to that recorded before for the non-girdled shoots under other conditions. The extreme variations are not found as on the girdled

shoots but there is a correlation with the leaf area and size of the nut. It will be noted that the weight of nuts from groups with leaf surface over 150 square cm varied little; 150 to 200 square cm or five leaves to a nut seemed to give about as large normal nuts as greater areas. Areas of over 300 square cm per nut show all nuts as normal, but such large foliage areas do not occur generally under natural conditions.

Measuring of the leaves is slow work. A correlation between the length of shoots and the leaves on the shoots bearing nuts was determined as .8989 ± .0056. Such a close correlation might warrant the use of shoot length in place of leaf area in later studies.

A Preliminary Report on Growth Rate Studies on the Pecan

By ATHERTON C. GOSSARD, *U. S. Department of Agriculture, Spring Hill, Ala.*

STUDIES on the growth rate of pecan shoots in relation to the production of pistillate blossoms and nuts were started at the United States Pecan Field Station, Spring Hill, Alabama, in 1931.

Bearing pecan trees, 13 years old, of the Schley, Stuart, and Success varieties, in an orchard in Mobile County, Alabama, were used. In the spring of 1931, before growth started, selected shoots produced in 1930 were classified according to length into three classes: A, up to 4 inches long; B, from 5 to 12 inches long; and C, 13 inches and longer. The shoots were measured to the nearest inch and labelled. Each 1931-shoot growing from the 1930 parent shoots was labelled and its length measured to the nearest 0.1 inch at nearly weekly intervals throughout the growing season. The fully developed blossoms were counted on May 14 and 15, a short time after pollination had occurred. The number of nuts on each bearing shoot, as recorded on October 16 for Schley and Success and on November 9 for Stuart has been considered as the number of nuts matured.

The data for the growth rate, expressed as cumulative growth, of the different types of shoots for the Schley and Success varieties are presented in the form of graphs. Although the data for the Stuart variety are discussed the graphs are omitted, as they show the same tendencies as do those for Schley and Success and, in general, the curves representing them lie between those for the latter two varieties.

GROWTH OF NEW SHOOTS IN RELATION TO LENGTH OF PARENT SHOOTS

The cumulative growth of the shoots of the different classes, regardless of whether or not they blossomed or bore nuts, is shown by the curves in Fig. 1. In this figure the classes A, B, and C represent the 1931 shoots which grew, respectively, from the shoots in the 1930 A, B, and C classes. Thus the shoots in Class A in Fig. 1 grew from the 1930 shoots which were 4 inches or less in length. As may be seen from this figure, as the length of the 1930 parent shoots, as represented by the 1930 classes, increased, the average growth rate throughout the season and the average total length of the 1931 shoots produced by them increased correspondingly. This is true for each variety and indicates not only that the longest shoots of one year produce the most rapidly growing and longest shoots of the following year, but also that the shoots which make the most rapid growth at the beginning of the growing season attain the greatest total length by the end of the season.

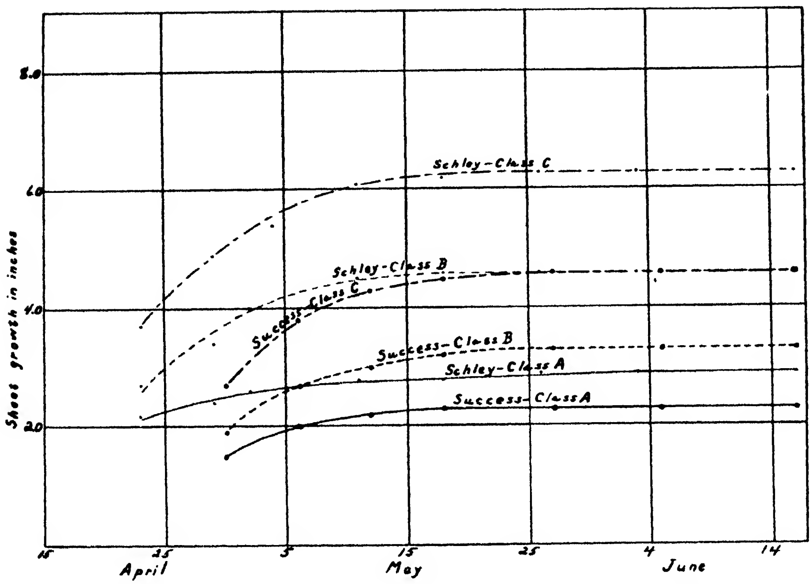

FIG. 1. Cumulative growth of 1931 pecan shoots produced by certain classes of 1930 parent shoots.

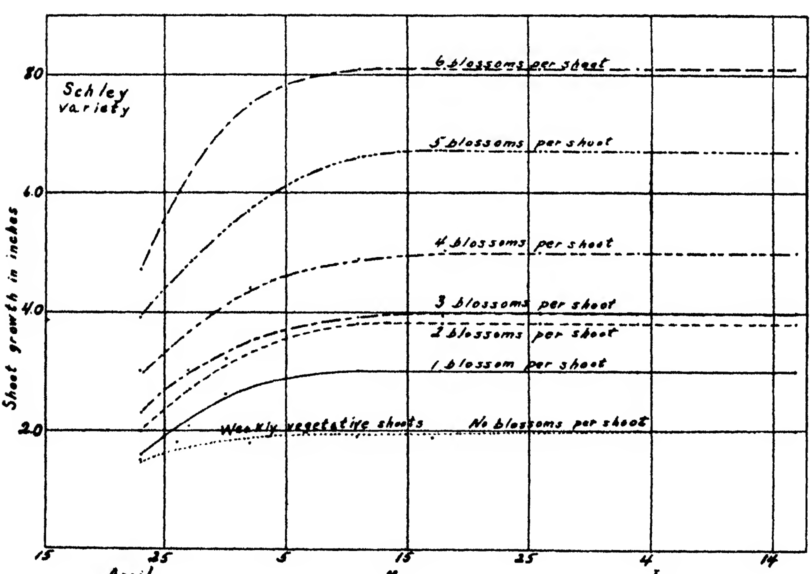

FIG. 2. Cumulative growth of 1931 blossoming shoots in relation to the number of blossoms formed. Schley variety.

Growth Rate in Relation to Number of Pistillate Blossoms

The relation of the average growth rate and total length of the 1931 shoots to the number of pistillate blossoms formed is shown in Figs. 2 and 3. The growth rate and total length have increased directly with the number of blossoms produced. One exception, not shown by the graphs, occurred in the case of Stuart. The shoots of this variety which produced one pistillate blossom per shoot had a slightly higher growth rate and total length than did those which produced two blossoms each.

In Schley the average growth rate and total growth of the shoots which set blossoms were greater than those of the shoots which did not bloom. The non-blossoming shoots of this variety are classed as weakly vegetative, none of those which occurred among the shoots used in these studies having exceeded 4 inches in length. Of the Stuart shoots, only two, averaging 5.4 inches total length, could be classed as strongly vegetative. The average total length of the weakly vegetative shoots was 2.3 inches, 0.5 of an inch less than that of the shortest blossoming shoots. In Success, which produced more non-blossoming shoots 5 inches or longer, the strongly vegetative shoots grew nearly as rapidly at the beginning of the season as did those which produced five blossoms per shoot, continued their rapid growth longer than any of the classes of blossoming shoots and attained the greatest average total length of the shoots in any class. The weakly vegetative shoots attained a greater average total length than did those which formed one blossom per shoot although they were shorter in the early part of the season. Their average growth rate and total length were less than those of the shoots producing two or more blossoms.

The curves in Figs. 2 and 3 indicate that, in general, the blossoming shoots having the lowest rate of growth and attaining the least total length produce the fewest blossoms per shoot, while those which grow most rapidly and reach the greatest length blossom most heavily.

Growth Rate in Relation to Number of Nuts Matured

The average growth rate of the shoots in relation to the number of nuts matured is shown by Fig 4. The curves marked "No nuts per shoot" represent the growth of shoots which set blossoms but failed to mature nuts. The data presented in this graph show that the rate of growth of the shoots increased as the number of nuts matured per shoot increased, without exception for Success and with only one exception in the case of Schley. The cumulative growth curves for the Schley shoots which matured two nuts per shoot crossed, with the curves for the shoots which matured two nuts being higher for all dates after May 5, indicating a greater average total growth of these shoots. The growth rate of the Stuart shoots also increased as the number of nuts matured per shoot increased without exception. The total growth of the shoots of the Schley and Stuart varieties, in rela-

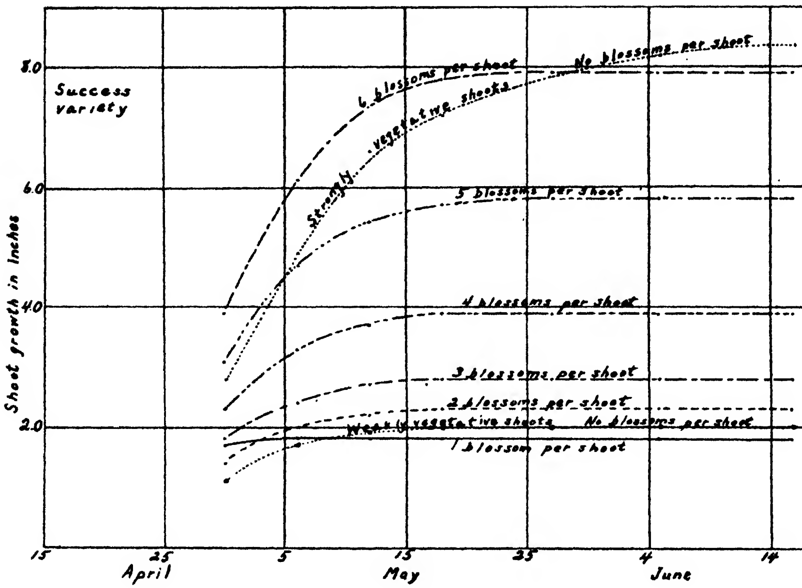

Fig. 3. Cumulative growth of 1931 blossoming shoots in relation to the number of blossoms formed. Success variety.

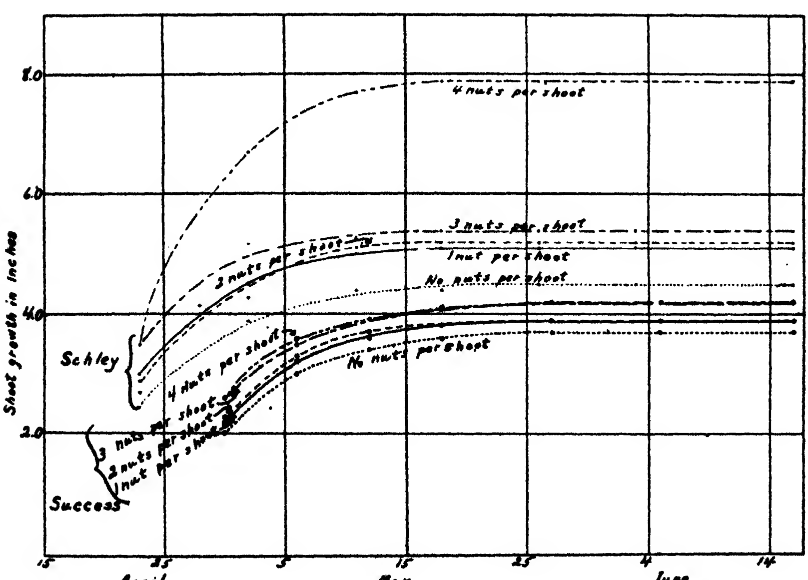

Fig. 4. Cumulative growth of 1931 blossoming shoots in relation to the number of nuts matured.

tion to the number of nuts matured, also increased without exception as the number of nuts increased. The Success shoots which matured one nut each attained the same average total length as did those which matured two nuts. The Success shoots which matured three nuts each attained the same average total length as did those which matured four. In each of these cases, however, the early growth rate of the shoots which matured the larger number of nuts was the greater.

The data presented graphically in Fig. 4 indicate that the number of nuts matured per shoot is directly related to the rate of growth and total length of the shoots on which the nuts are borne.

Comparison of Growth-Blossom and Growth-Nut Ratios

A comparison of the cumulative growth curves in Fig. 4 with those in Figs. 2 and 3, shows that in Schley the average growth rates and average total lengths of all the groups of shoots which matured nuts were greater than those of the shoots which formed one, two, three and four blossoms each, respectively; and that, in Success they were greater than those of the shoots which produced one, two, and three blossoms per shoot. The average growth rates and total lengths of all the groups of Stuart shoots which matured nuts were greater than those of the shoots of this variety which bore one and two nuts per shoot, respectively. A comparison of Fig. 4 with Figs. 2 and 3 shows also that, without exception, the average growth rate and the average total length attained by the shoots which matured a certain number of nuts were greater than those of the shoots which set the same number of blossoms.

These facts indicate that the blossoming shoots of low growth rate and of little total growth drop most or all of the blossoms or of the nuts before they are matured, and that shoots making more rapid growth and attaining greater total length are required to mature any certain number of nuts than are required to set the same number of blossoms in the spring.

Coating Pecan Trees With Paraffin in Experimental Stage and Still an Unsafe Practice

By H. L. CRANE and GEORGE P. HOFFMANN, *U. S. Department of Agriculture, Washington, D. C.*

THE failures which usually followed the early attempts to graft nut trees, except almonds, by the methods employed in propagating varieties of the common fruit trees, are now history. Experience has shown that the immediate cause for these failures to secure a "live" was due to the grafts not being sufficiently well protected against drying out and not to the manner of setting the scions. These failures were turned into successes by covering the wounds and entire scion, including buds, with a wax which excluded the air and prevented them from drying out until the scion united with the stock. The idea of using a melted wax to cover the scion, as well as the wound, originated with E. A. Riehl of Godfrey, Illinois, according to Morris (1). Riehl passed the idea on to the late J. F. Jones of Lancaster, Pennsylvania, and he to Morris. Various waxes were used, but Morris developed the method of using paraffin. The success met with in securing a high percentage of living grafts by this method of protecting the scions led to trials with paraffin as a coating for transplanted trees in an attempt to insure a higher percentage of living trees and stronger growth than usually results from uncoated trees. Neilson (2), in later studies, found the desiccation of transplanted fruit and ornamental trees to be reduced by coating them with paraffin. This work encouraged the practice of coating trees with a wax in order to prevent losses from transplanting. Tukey and Brase (3), working with cherry trees, reported that "paraffining improved neither the growth or stand, but actually resulting in slightly poorer growth and poorer stand in some instances." Jacobs (4) reported severe injury resulted on beech, sugar maple, and walnut trees from coatings of paraffin when used alone or in combination with other materials.

Pecan trees, when transplanted from the nursery to the orchard, are very slow to start growth, even though planted under the most favorable conditions and they usually make little new shoot growth the first year. In some sections of the pecan producing territory April and May may be dry. For these reasons any treatment, such as coating with paraffin, which would tend to overcome the difficulty of securing a high percentage of living trees in a newly planted pecan orchard, would be welcomed by the planter.

Some southern nurserymen, after some trial, adopted the practice of coating pecan trees with paraffin soon after they were dug from the nursery. Trees so treated have, in general, been well received by the nursery trade. Some dealers have reported that their calls for replants on account of dead trees have been about half what they were before paraffin coating was practiced, and they are so enthusiastic over this process on pecan trees that they do not want to handle

uncoated trees. One large pecan nursery which grows trees for the trade has paraffin-coated its entire production for several years. This nursery reports receiving no complaint whatever from its dealers regarding injury from the coating. Paraffin-coated pecan trees have been widely planted in the South and it would seem that in only a very few cases has injury from this treatment been reported.

On the U. S. Pecan Field Station at Philema, Georgia, several hundred pecan trees were coated with ordinary commercial paraffin (parawax) in 1929, after they had been planted in the orchard. This paraffin was melted in a Clarke melter and applied to the trees with a brush. The results secured from this treatment were generally satisfactory, although in a few cases some injury resulted. No careful records were taken of the percentages of dead trees among those coated or uncoated and no counts were made of trees injured by the paraffin coating. The trees affected showed the injury at the point of union of the stock and scion and only on the west side of the trees. During the growing season no injury was evident and it was late fall before it was noticed. During the following 2 years the injury was repaired by tree growth and no permanent damage resulted.

In the early spring of 1933 more than 2400 pecan trees were planted near Meridian, Mississippi, on Orangeburg soil which had been in cotton the previous year. The trees used in planting this orchard were as follows:

Success, 600 trees, 1-year-old top, 3-year-old root.
Schley, 600 trees, 1-year-old top, 3-year-old root.
Moneymaker, 600 trees, 2-year-old top, 4-year-old root.
Moore, 560 trees, 2-year-old top, 4-year-old root.
Schley, 40 trees, 2-year-old top, 4-year-old root.

These trees were dug from the nursery rows the last days of February and immediately packed and shipped to Meridian. The 2-year-old trees were received February 27 and the 1-year-old trees March 3. When the trees were received they were carefully heeled in until they were planted in the orchard. Planting began on March 6 and because of rain and cold weather, was not completed until March 20. In addition to the above, four trees each of a number of pecan varieties were planted.

All of the tops of the 1-year-old trees, to the point where they were budded, were dipped at the nursery in a melted paraffin bath. This paraffin had a reported melting point of 132 degrees F, and the bath was maintained at a temperature much higher than this: *i. e.,* from 160 to 180 degrees. In dipping the nursery trees, the top is submerged in the melted wax and removed as quickly as possible. This procedure causes a thin, even coating of paraffin to be deposited over all parts of the tree top. A careful, tree-by-tree inspection made the first week in April to determine the relation, if any, of paraffin coating to the budding out of the trees, showed that the coated 1-year-old trees were budding out much more rapidly than the uncoated 2-year-old trees, although all the 2-year-old trees had been planted before any of the 1-year-old trees were set. Since the coated trees started off so

much better than uncoated trees, practically all of the uncoated trees, including all 2-year-old trees, were coated with paraffin by brush application. A paraffin having an average melting point of 125 degrees F was used and it was applied approximately 2 weeks after these trees had been planted in the orchard. The temperature of the paraffin was kept just above its melting point and for this reason, when it was being applied to the cold trees it solidified quickly, causing a much heavier deposit of paraffin on these trees than that on the 1-year-old trees which were dipped at the nursery.

The resulting effects of coating the trees with paraffin were closely watched and there was very convincing evidence that this treatment had merit. By May 6, trees which had shown no activity became active and produced shoot growth and the bark appeared to be in a good, healthy condition. The condition of the paraffin-coated trees continued to improve; however, on May 20, it was observed that many of the trees had what looked to be an oil-soaked area extending from the top to the base and appearing on the west side of the trees. The general appearance of this oil-soaked strip, covering approximately one-third of the bark surface, was much the same as that produced by sunscald on apple trees. At this time there appeared blisters in the paraffin coating which, when broken open, were found to contain liquid. It remains to be determined whether this moisture was exuded normally by the trees and kept from evaporating by the paraffin coating, or whether the paraffin oil penetrated the tissues, causing their death, and replaced the water which was exuded under the surface of the paraffin coating. Oak and elm responded to the paraffin treatment in the same way as pecan trees. The important point to be brought out here is that prior to May 20 the highest temperature recorded by the U. S. Weather Bureau at Meridian, 5 miles from the orchard, was 90 degrees, and the lowest melting point paraffin used was 125 degrees F.

That the paraffin actually melted was shown by the soil being oil-soaked on the west side of the trees where it had accumulated after running off the tree trunk. Lumps of soil thrown against the tree trunks by cultural operations were soaked with oil at the point where they came in contact with the trees, to a depth of ¼ to ¾ inch. Furthermore, in some cases leaves on short shoots came in contact with the oil and were burned.

The melting of the paraffin was probably due to the absorption and accumulation of heat under the paraffin coating. That there are wide differences in the temperatures of the opposite sides of the tree trunks has been shown by Mix (5). At Ithaca, New York, he found the temperature of the inner bark and sapwood on the southwest side of a tree to be as much as 39 degrees F higher than that on the northeast side, and when the tree trunk was blackened with tar, the temperature on the same day, February 20, 1915, was 57 degrees higher on the southwest than on the northeast side of the tree. It is also quite possible that the coating of paraffin may act similarly to a pane of glass in that it changes the light rays of the sun into heat rays, causing the temperature to be greatly increased. The coating of

paraffin, until it was destroyed by melting, would tend to prevent the radiation of heat from the tree trunk. The color of the oil-soaked bark, which is much darker than normal, would be another factor of importance in raising the temperature of the tree trunk.

As the season advanced and higher temperatures occurred, the oil-soaked areas on these trees continued to become more and more evident, except on those trees which previously had, or had recently produced, sufficient side branches and foliage to shade the west side of the trees. An examination of the trees on September 29, 1933, showed the following:

	Percentage of 1-year-old trees	Percentage of 2-year-old trees
Entirely dead	12.50	22.11
Badly injured (most of which will die)	35.42	67.47
Slightly injured (may live if borers and woodrot can be kept out)	36.46	10.52
Free from injury	15.62	.0

No difference in the amount of injury from the paraffin has been correlated with varietal peculiarities, location in the orchard, or soils. The data show that the injury was much more serious on the 2-year-old trees than on the 1-year-olds. The most plausible explanation for this result is probably the fact that a less regular and much thicker coat, of paraffin said to have a lower melting point, was used on the 2-year-old trees. It is also quite possible that the thicker coat of cortex on the 2-year-old trees permitted a greater accumulation of heat, causing more injury to the cambium than on the 1-year-old trees. Possibly the greater curvature of the trunks of the young trees permitting a given point on the trunk to be exposed to the direct sun for a shorter time, contributed to the smaller injury.

The injury in this orchard occurred on the west side of the trees, with the greatest injury taking place at or near the point where they were budded. This has most probably been due to the paraffin melting and running down the tree trunk and accumulating at that point and to a greater absorption of heat reflected from the soil. In some cases the paraffin ran down the trunks and soaked the soil on the west side of the trees. The injured bark has an oil-soaked or sun-scalded appearance. Where the paraffin has not all penetrated the bark or run off the trunks the coating has a blister-like appearance and the bark underneath has changed from a healthy, green color to a sooty black. In this orchard, a limited number of trees which were not coated with paraffin have shown no injury and have made as good, vigorous growth as could be expected of trees the first year following transplanting. Furthermore, the paraffin-coated trees, even though apparently uninjured by the treatment, shed their leaves gradually during late summer and fall, while the uncoated trees shed their leaves normally.

From the observations made on this farm during the past summer on the effects of paraffin coating of pecan, oak, and elm trees, it

must be concluded that this treatment is a questionable practice, still in the experimental stage, which may result in serious injury or death of the trees. These observations show that injury resulted from paraffins having an average melting point of 125 degrees F and 132 degrees when the maximum air temperature was only 90 degrees. This is a difference of 35 to 42 degrees between the air temperature and that of the melting point of the paraffin used. In the South, where the air temperature may be 100 degrees or above for several days at a time and where the soil temperature at the surface reaches a maximum of at least 30 degrees above air temperature, even a paraffin having a melting point of 150 to 160 degrees would seem to be unsafe.

The injury to the trees in this orchard seems to have been somewhat proportional to the amount or thickness of the coating of paraffin deposited on the trees, since the trees that were dipped appeared to have had the thinnest coating and showed the least injury.

The cause of the injury resulting from the paraffin coating has not been determined, but it would seem to have been due to the accumulation of heat so that the temperature of the tissues killed was above the death point. Whether the paraffin oil penetrated the tissues before or after death remains to be determined.

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Using the Normal Frequency Curve in Pomological Research

By R. D. Anthony, *Pennsylvania State College, State College, Pa.*

THE question of the number of plants desirable to use in any pomological research has caused much worry and some controversy for many years. The answer is not so difficult when the contrasts to be studied are easily defined, where something is known of the optimum for this particular factor and when the number of variables is kept very small. Such simple experiments involving the amount, composition, or source of a fertilizer as it influences yield may now be planned with a reasonable degree of certainty that plot size and lack of uniformity will not lead to such large probable errors as to make the results of questionable value. This is not the case when we wish to study a single factor through a considerable range or to determine the effect of one variable upon another.

Seven years ago it seemed desirable for the Department of Horticulture at The Pennsylvania State College to attempt a study of the interrelation of the use of nitrogenous fertilizers and incorporating chopped green rye—top and roots—into an orchard soil. For this study apple trees were planted in 42 boiler plate cylinders, each containing nearly 90 cubic feet of soil. At the beginning of the experiment a high degree of uniformity was secured by the same methods used in a previous experiment (1).

These rims, as we have called them, are sunk in the ground in a rectangle six rows by seven and are spaced at 20-foot intervals. The trees for this experiment were planted in the spring of 1928.

Beginning with 1930, row 1 has received no green material; row 2 annually has had one unit (usually 1 kilogram) of chopped green rye dug into each rim; row 3 has had two units and this increase has continued until row 7 has had six units. At right angles to this treatment, tree 1 in each row has received no nitrogen in commercial fertilizer; tree 2 has had one unit; tree 3 two units; and finally, tree 6 five units. In 1930 and 1931 the unit was 70 gms. of nitrate of soda and was put on in a single application; in 1932 and 1933, the unit was 157.5 gms. of sulphate of ammonia, $^2/_3$ put on in May and $^1/_3$ in June. Thus, under this plan, each of the 42 rims receives a different treatment ranging from nothing up to six units of rye combined with none up to five units of nitrogen. This arrangement is similar to the three-salt triangle used by Shive (2) and others in nutrition experiments with many annuals but is unusual for pomological research.

Three types of records have been taken; soil condition, tree growth, and chemical composition of leaves.[1] As soon as this experiment was under way the immediate question was the method to be

[1]The chemical studies have been under the direction of Dr. Walter Thomas of the Department of Agricultural and Biological Chemistry.

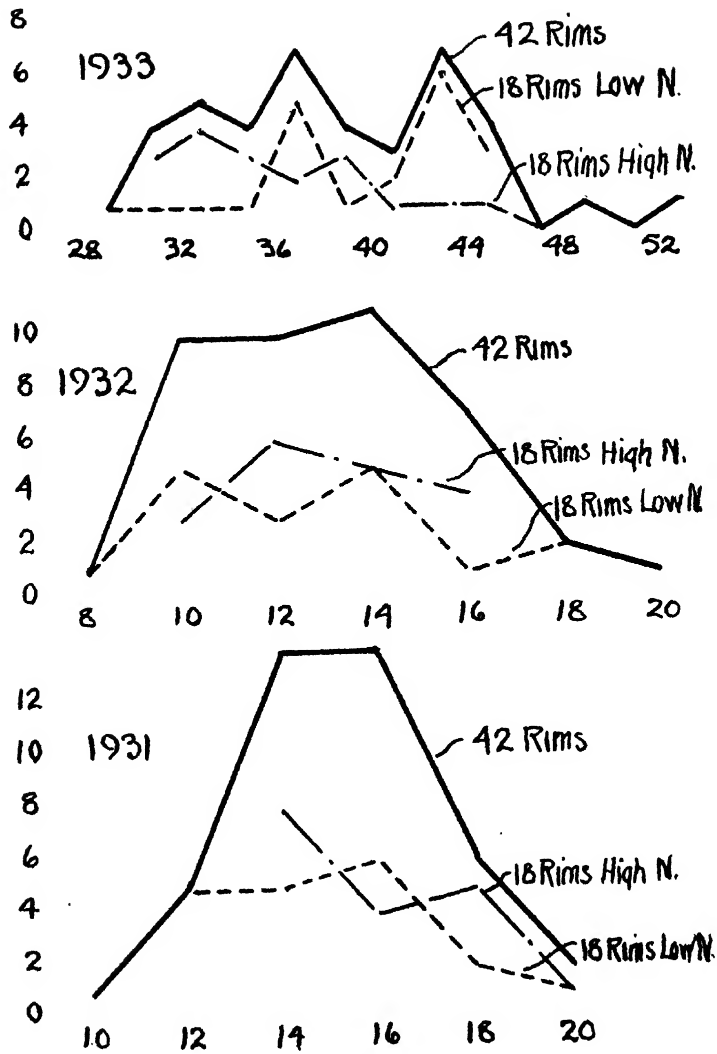

FIG. 1. Frequency curves showing total annual branch growth in centimeters (00 omitted).

used in interpreting these results. When any single factor is studied in a biological group in which all the members are exposed to the same environment the records, when plotted as a frequency curve, will approximate the normal frequency curve in which the mean and mode coincide and the halves are symmetrical. Any departure from this symmetry may be taken as indicating the differential action of some environmental factor or factors.

Although 42 individuals would not supply enough records to give a smooth curve, it was decided that the conditions surrounding these rims were sufficiently uniform, except for the variables of the treatment, so that, if all records were plotted as frequency curves, departure from the normal curve might reasonably be assumed to be due to the treatments given. The fact that it would be possible to compare curves for the same factor from the same individuals from year to year makes it safer to draw conclusions from such curves.

In Fig. 1 we have a picture of the change which has taken place in the annual growth curve the second, third and fourth years after the beginning of the differential treatments in these 42 rims. The bimodal curve in 1933 would lead us to assume that two factors had been influencing growth. To find the influence of the nitrogen applications the frequency curve of 18 rims receiving none or low applications was plotted in comparison with the curve for the 18 rims receiving the higher applications of nitrogen. (The fourth tree in each row was omitted here merely because it had also been omitted in a similar study of the effect of applying varying amounts of rye in order to give two groups of equal numbers). In 1931, the trees receiving the larger applications of nitrogen in nitrate of soda contribute to the higher portions of the frequency curve of all the rims and the trees receiving the lower amounts to the lower part of the curve. In 1932, the records of the high nitrogen trees are confined to the middle portion of the curve of all the trees. In 1933, the low nitrogen trees are contributing more to the higher portion of the curve of all the trees and the high nitrogen trees to the lower portion of the curve. This change in 3 years would suggest that the heavier nitrogen applications have checked growth. Since we knew that the heaviest applications puddled the soil it is possible that this puddling has had an injurious effect on tree growth.

In addition to plotting these frequencies, the locations of the individuals in the upper and lower quarters of many of the curves have been spotted on a quadrangle in which all rims and treatments are indicated.

These methods of analyses have now been given a rather thorough test not only with the records of tree growth but also with those chemical analyses which are now available. The results are so satisfying that we feel we shall be able to present a very complete picture of the results and to trace the development of these results from year to year when this experiment is completed.

Ultimately it may be desirable to study the mathematics of some of these curves but in all this early work this has seemed neither necessary nor desirable. Consequently a considerable number of

records can be plotted quickly and the results of one year compared with others readily. This represents a wide departure from studies of coefficients of variation, plot means and probable errors or even from "Student" odds but the system seems to work.

Is this method of analysis usable in types of pomological research other than preliminary exploratory work? Since the method is primarily a study of the causes leading to departures from the normal curve, the material to be studied must, at the beginning, be sufficiently uniform for the records to approximate such a curve. In field plantings at State College we have several hundred apple trees of the age of the trees in the rims or younger. These trees are being used in nutrition experiments. The early tree growth records of these trees, when fitted to frequency curves, approximate the normal curve. The frequency distribution of the later records seems to present a more satisfactory picture of tree performance than it is possible to secure at present from a study of plot records for the same trees.

The use of frequency distributions in studying the records from mature trees showing a high degree of variability at the beginning of the experiment has not been satisfactory.

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Ground Water as a Measure of the Suitability of a Soil for Orchard Purposes

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IN a previous publication (1) ground water measurements were suggested as a practicable means of determining orchard drainage conditions. The present paper gives the results of further studies and observations of this method. The term ground water is here used to designate a temporary or suspended water table which is caused by the accumulation of free water in the soil in the fall, winter and spring, while its loss thru evaporation and transpiration by plants is low. It is seldom found during the height of the growing season. It is not to be confused with the more permanent water table such as would be represented by the water level in dug wells, altho the two may occasionally be related. The depth to ground water is a single, direct measure of the many factors operating to influence drainage conditions. It will necessarily vary from season to season with climatic conditions.

METHODS

A large number of test wells being required for this study of ground water, it was desirable that they be simple and inexpensive to install. A hole 4 feet deep was made with a soil auger and into this was dropped a galvanized iron tube ¾ inch in diameter and 4 feet long. The tube was a piece of 28 gauge sheet iron rolled into the form of a pipe so that the edges lapped slightly. This left a very small crack extending the whole length of the tube so that any water in the soil moved into the tube at once. These pipes were made by a local tin shop at a price of about 15c in lots of 200. Gas pipe or similar material may be used but unless it is well perforated there may be a lag of several days between the actual water reading in the soil and in the pipe. The hole without any pipe may suffice for making observations during a period of a month or 6 weeks if the soil is a silty clay or heavier. The purpose of the pipe is to keep the sides of the hole from sloughing off into the hole and interfering with the readings. In some soils, mud will settle in the bottom of the pipe but can be easily cleaned out by withdrawing the pipe, grasping it at one end and giving it a whirling motion. The depth to ground water or the distance from the soil surface to the water surface is measured with an ordinary folding carpenter's rule to the nearest inch. The ruler should not be inserted far enough into the hole to displace the water an appreciable amount and thus alter the true reading.

Discretion must be used in the time to take the readings. Readings obtained before rains, (light showers have little influence) will give the maximum drying out effect between rains. Though readings immediately after heavy rains will indicate the extent to which different locations fill with water,—the important thing under conditions of

this investigation is, the depth to which the water is able to recede within a few days after the rain. Some good fruit soils fill with ground water to within a few inches of the surface after very heavy rains, but in the course of an hour or two the water falls rapidly and in a day or two will be back nearly to the level obtaining before the rain. Readings could well be taken at intervals of about 3 days.

Likewise there is little to be gained by starting measurements in the spring before the ground has thawed out and has become settled and adjusted to normal spring conditions. While this will vary with the season, usually when apples are in the green tip stage will be sufficiently early in Western New York. Much before this, ground water readings may be erratic and difficult to reproduce with consistency. In fact some good fruit soils show ground water close to the surface at this early season.

Relation of Ground Water to Yield

An orchard at Hall, New York, on Ontario fine sandy loam was well suited to study the extent to which ground water measurements can be relied upon to differentiate between border line conditions, where comparatively small differences in soil profile exist, but where tree yields are widely variable. Ten-year yield records of 49 individual Baldwin trees in this 35-year-old orchard were available. Two ground water measurements were taken at each tree on April 26, May 16, and May 26. When the depth to ground water on May 16 is correlated with tree yields, the correlation is significant, being .678 ± .05. This is at the time of full bloom and although the correlation is slightly higher than those obtained on the other two dates, the graph shown in Fig. 1 is typical.

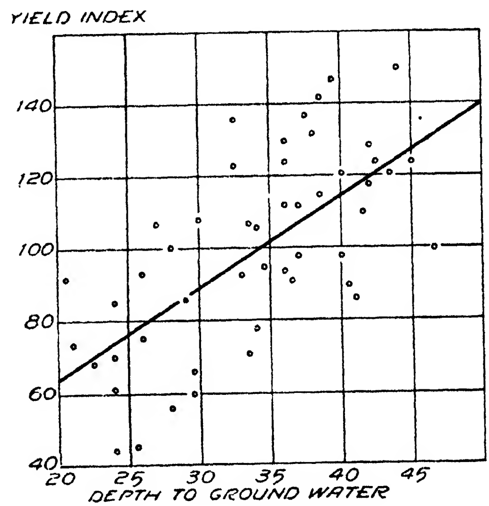

Fig. 1. Relation of yield of 35-year-old Baldwin apple trees to the depth to ground water on May 16, 1933, at Hall, N. Y. The yield index expresses the yield of each tree as a percentage of the average annual yield of all trees during the 10-year period. The depth to ground water is expressed as the number of inches from the ground surface to the free water surface in test holes at each tree. r = .678 ± .05. A line of best fit has been constructed.

The depth to ground water is also correlated with pH and confirms what was suspected a year ago that where drainage is slow there is a less rapid leaching of the basic elements, resulting in a higher pH

value (2). Recent studies of the oxidation-reduction potential of these same soils shows that this factor is closely associated with pH, yield, and ground water and that it may be a useful index of subsoil drainage conditions over a longer period than ground water (3).

In order to learn something of the number of observations necessary to furnish a true picture of ground water conditions, the 294 measurements were examined statistically and it was found that taking observations at every eighth tree (about 4 to the acre) gave results as accurate as those secured from more numerous measurements, under these conditions.[1]

Some Factors Influencing Depth to Ground Water

In Table I is shown the effect of topography and texture of subsoil on depth to ground water in the Pomology orchard at Ithaca, New York, 1933. This soil was mapped as a Dunkirk silty clay loam. In the area with slightly more slope and a lighter textured sub-soil

TABLE I—The Effect of Topography and Texture of Subsoil on Depth to Ground Water at Ithaca, N. Y., 1933 (Observation Stations 10 Ft. from Tree; Grass and Weed Vegetation, Unmulched)

Date	Period	Depth from Soil Surface to Ground Water Level in Inches*			
		Topography Undulating (1 per cent Slope) Clay Loam soil; Heavy Clay Subsoil		Topography Rolling (5 per cent slope) Silt Loam Soil; Silty Clay Subsoil	
		Duplicate Locations		Duplicate Locations	
		A[1]	B[1]	K[1]	L[1]
3/31	Buds swell	8	9	13	10
4/3		9	5	9	7
4/5		6	6	9	8
4/10		7	7	9	9
4/14		6	7	8	9
Average........		7	7	10	9
4/18	Pre-bloom	2	2	5	4
4/20		6	6	10	10
4/22		10	10	14	14
4/29		13	12	20	19
5/3		6	4	13	12
5/5		11	11	19	18
Average.......		8	8	14	13
5/8	Bloom	14	12	20	20
5/12		18	15	24	22
5/15		25	22	30	29
Average........		19	16	25	24

*Each figure is an average of 8 or more stations.

[1]Credit is due S. R. Levering, graduate student in the Department of Pomology, for the statistical computations.

the ground water surface was roughly 50 per cent lower than in an adjoining area with less slope and a heavier sub-soil.

It so happens that at Ithaca on these same soils the yield of 20-year-old McIntosh apple trees during a 12-year period averaged 50 per cent greater where the ground water was lower. Practically no McIntosh trees were missing on either soil. Where the surface was flatter and the subsoil heavier, a considerable percentage of the Baldwin trees, on the other hand, had died. The Baldwin trees were of the same age as the McIntosh and were producing unsatisfactory crops. Unfortunately since there were no Baldwin trees comparable to the McIntosh on the better drained soil a comparison of yield is impossible. However this behavior bears out frequent field observations of the greater susceptibility of Baldwin trees to water-logged conditions.

TABLE II—THE EFFECT OF A HEAVY STRAW MULCH ON THE DEPTH TO GROUND WATER WHERE THE SUBSOIL IS HEAVY CLAY. (OBSERVATION STATIONS 6 FT. FROM TREE, ITHACA, 1933)

Date	Period	Stations 4 Feet from Drain Tile		Stations 16 Feet from Drain Tile	
		Unmulched B	Mulched B'	Unmulched B	Mulched B'
5/2	Pre-bloom	23	15	19	15
5/3		15	4	9	6
5/5		19	11	14	11
Average		19	10	14	11
5/8	Bloom	20	13	16	13
5/12		25	18	22	16
5/15		30	26	28	25
Average		25	19	22	18

The effect of a mulch on the depth to ground water when the subsoil is heavy is shown in Table II. Though a sod system of management may be advisable in an orchard where drainage is slow, the use of a heavy mulch under such conditions seems at least questionable from the data. A heavy mulch keeps the ground water closer to the surface and this is particularly evident within the functioning range of a tile drain.

The question is often raised, will not tile drains lower the ground water sufficiently to overcome the slow drainage in a heavy soil. Table III sheds some light on this problem. The data is for the same orchard area reported on in Table I. The heavy clay soil was tile drained before the orchard was planted. The silt soil was not tiled, but readings of ground water were made at equivalent distances from the trees for comparison. The tile were laid 40 feet apart with the trees set on the triangular system, each tree row 10 feet from each line of tile. The data show the ground water has been lowered considerably, within 4 feet of the tile, but very slightly at distances 16 and

20 feet from the tile. Even within 4 feet of the tile the ground water was not as far below the surface on the clay soil as it was on the silt soil without tile, during the critical period of bloom. Due to the limited distance that drain tile will draw in a heavy soil it would seem necessary to lay them much closer than 40 feet in order to secure beneficial crop responses in an orchard. It should be noted that the precipitation during the season studied was below normal, which suggests that even though artificial drainage is provided every 20 feet, its practical success for orchard purposes on land of this character is to be doubted.

TABLE III—Tile Drain in Relation to Depth to Ground Water. (3-inch Drain Tile, Set 24-30 Inches Deep; Grass and Weed Vegetation, Unmulched, Ithaca, 1933)

Date	Period	Depth from Soil Surface to Ground Water Level in Inches*									
		B—Clay Loam Soil; Heavy Clay Subsoil Distance from Tile in Feet					L^1—silt Loam Soil; Silty Clay Subsoil Equivalent Distance;no Tile				
		½	4	10†	16	20	½	4	10†	16	20
3/31	Buds Swell	13	—	—	—	8	10	—	—	—	10
4/3		11	—	—	—	9	8	—	—	—	7
4/5		12	—	—	—	6	9	—	—	—	8
4/10		13	—	—	—	7	10	—	—	—	9
4/14		13	—	—	—	6	10	—	—	—	9
Average........		12	—	—	—	7	9	—	—	—	9
4/22	Pre-bloom	18	20	—	12	10	15	18	—	16	14
4/29		19	21	—	14	13	19	23	—	20	19
5/3		13	15	—	9	6	14	18	—	16	12
5/5		18	19	—	14	11	19	23	—	20	18
Average........		17	19	—	12	10	17	20	—	18	16
5/8	Bloom	20	20	—	16	14	21	25	—	23	20
5/12		22	25	—	22	18	26	30	—	27	22
5/15		28	30	—	28	25	33	37	—	33	29
Average........		23	25	—	22	19	27	31	—	28	24

*Each figure is an average of 8 or more stations.
†Position of tree.

Table III shows that the ground water is lower at 4 feet from the tile (6 feet from the tree) than nearly at the tile (10 feet from the tree). This difference represents the lowering of the ground water, by the tree itself.

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The Effect of Irrigation on the Occurrence of a Form of the Cork Disease and on the Size of Apple Fruits

By A. B. Burrell, *Cornell University, Ithaca, N. Y.*

FOR the past 8 years (1) in the Champlain Valley of New York, the author has been studying the apparently related non-parasitic apple diseases discussed by Mix (2), under the names cork, drouth spot, drouth dieback, and drouth rosette, respectively. Ultimately a general paper will be published dealing with the literature and all phases of these investigations. Certain of the 1933 results, however, seem of sufficient interest to warrant their immediate publication.

Different writers on this group of diseases have used a somewhat variable terminology. However, the prevailing practice has been to consider as cork, those cases in which the characteristic symptom is the presence of large roundish or irregular masses of dead cells in the flesh of the fruit often near the core, regardless of whether the surface is regular or deformed. Drouth spot is the name generally used when there are large continuous dead areas at the surface (2, 4). This usage will be followed in the present report.

According to the foregoing definitions, the disease prevalent during 1933 in the Champlain Valley would be classed as cork. The main symptom in all varieties was a diffuse browning of the flesh, especially near the core, (Fig. 1). This form of cork is apparently identical with that discussed by Latimer (3) and resembles that shown by Brooks and Fisher (4) plate 5, D, except for the absence of lesions such as their photograph shows near the surface of the fruit. Mix (2) does not picture exactly this form of cork.

The first stage noted, was a water-soaked appearance of the areas that later turned brown. When the disease had its inception within a few weeks of harvest, the affected tissue was spongy rather than corky. The lesions were drier and more corky at harvest time, if they were initiated earlier in the summer. Affected fruit ripens on the tree from 1 to 3 weeks ahead of normal fruit. This is often followed by heavy dropping, especially in the variety McIntosh.

It is not always possible to tell by external examination, which fruits are affected. Sometimes the surface of the fruit is pebbly, more or less like the normal surface of Twenty-ounce apples. This pebbly surface was most prevalent in Cortland, but was often encountered in McIntosh, Northern Spy and other varieties.

The largest, most highly-colored fruits are more often affected than the small, greener ones. The calyx of affected fruits may be more open than is characteristic for the variety, and the basin broader and shallower. In severely affected fruits even the flesh not browned is dry and lacks acidity, and the flavor is sometimes otherwise impaired.

From personal observation, specimens, and correspondence, it is apparent that this form of cork (Fig. 1) occurred in the following districts in 1933: Champlain Valley, Hudson Valley, and Lake Ontario districts of New York, the States of Vermont, New Hampshire,

Maine, Massachusetts and Connecticut, and the Canadian provinces of Ontario and Quebec. The loss in different orchards varied from none to 75 per cent of the crop, but in most districts only a small percentage of the apples was affected. In the Champlain Valley of New York, it amounted to perhaps 6 per cent of the total crop. The difficulty of sorting them out largely prevented the usual local cash sales to wholesale buyers in that district. During previous years, this form of the cork disease has been observed occasionally in the principal apple districts of New York and at scattered points in northern New England.

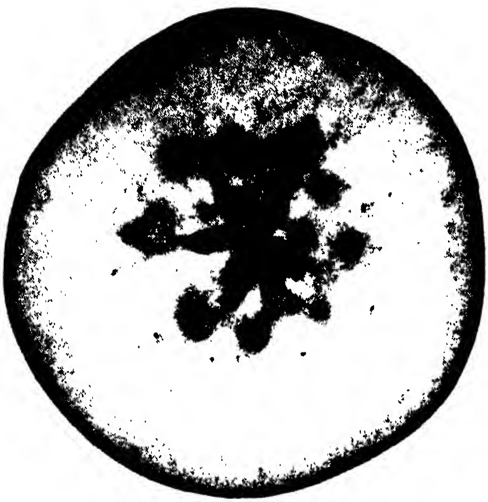

FIG. 1. Form of the cork disease prevalent in the Northeast in 1933. The slight darkening toward the periphery of the section is not a part of the symptoms. Variety, Baldwin.

In the regions where this form of cork was prevalent in 1933, the weather was in most cases drier than usual at least in midsummer. In some cases, the spring rainfall was excessive, while more nearly normal rainfall occurred in August and September. The monthly rainfall in inches near the orchard where Experiment I was conducted, together with deviations from the normal rainfall of the region serves to illustrate this: April, 3.03 (+1.02); May, 2.84 (+.40); June, 1.86 (—1.05); July .99 (—2.34); August 3.98 (+1.38); September 1.90 (—1.31).

Summer temperatures were above normal. All annual crops maturing in midsummer or later showed poor vegetative growth as a result of drouth. The moisture content of soil samples taken at a depth of 15 to 18 inches, based on dry weight of the soil, was below 5 per cent at several sampling locations in another part of the orchard of which the block used in Experiment I was a part. This was true of samples taken July 14, July 20, and August 11. This must not have been far from the wilting coefficient for the soil.

The principal losses were reported as occurring on the lighter soils, and in some cases, on the shallower soils underlaid by hardpan or rock. The disease was not restricted, however, to such soil types. Some of these lighter soils in western New York and the Hudson Valley are regarded as among the most desirable types for orchard purposes in the respective regions on the basis of their high production over a period of years.

The injury was more prevalent on trees of high vigor than on those

of low vigor. Thus, crops of trees receiving liberal quantities of nitrogen were more severely affected than crops of nitrogen-deficient trees. No statement concerning specific effects of other elements or of soil reaction seems justified at this time.

Fruits remaining very small throughout the season whether from water shortage or other causes were seldom affected. The disease was principally if not entirely on fruits that had sufficiently favorable growing conditions during part of the season to permit them to attain normal size.

Experiment I

This experiment was conducted in a moderately vigorous block of about 300 ten-year-old McIntosh trees, having an average limb-spread of 10 feet. The soil is Dover fine sandy loam which is moderately fertile and bears some limestone fragments. In 1932, perhaps 50 per cent of the fruits in this block were affected by drouth spot (using this term for the superficial type of injury) and a few of the trees developed what Mix termed "drouth dieback" of the terminal twigs, a symptom that commonly accompanies severe outbreaks of Mix's drouth spot. The block was mapped in 1932, the percentage of fruits affected with drouth spot and the prevalence of dieback being estimated for each tree. Ten trees in different parts of the block were chosen as having much more than average amounts of drouth spot. A few of them showed dieback. These trees were irrigated in 1933, ten applications being made between June 10 and September 6. The fruits were harvested before the last irrigation. Nine trees received 90 gallons and 135 gallons at each application, poured into a trench encircling the tree at a distance of 3 feet or less from the trunk. The extra amount of water on this one tree had no apparent effect.

Data were taken on these 10 irrigated trees and on 37 adjacent non-irrigated trees, 15 to 34 fruits selected at random being cut and examined for each tree. This is an extremely small number of fruits but the consistency of the results both on irrigated and non-irrigated trees was such that the results are believed highly significant. Only a trace of drouth spot occurred on any of the trees in 1933.

The average percentage of fruits affected with cork of the sort shown in Fig. 1, on the 10 irrigated trees was 16 per cent; the percentages on individual trees having been 0, 0, 6, 8, 13, 13, 25, 25, 29, and 44, respectively. The corresponding average for the non-irrigated trees was 82 per cent, the range having been from 31 to 100 per cent. (See Fig. 2.) Only one of the 37 non-irrigated trees showed less cork than the worst-affected irrigated tree. In general, the symptoms were much less severe even in the affected fruits of the irrigated trees than in the affected fruits of those not irrigated.

Twenty-two of the non-irrigated trees received about 600 pounds of Montreal stockyard manure apiece, in 2½-foot zone starting about 2 feet from the trunk in the fall of 1932. The average percentage of fruits affected in 1933 on these non-irrigated manured trees was 79 per cent. The average for 15 similar trees not manured was 85

per cent, an insignificant difference. Possibly this very heavy coating of manure which was sufficient to smother grass, conserved enough moisture to offset the effect of increasing the amount of cork that usually comes with increased vigor.

Experiment II

This experiment was conducted in a commercial McIntosh orchard, on Dover loam soil which is fertile, fairly well drained, with occasional limestone outcrops. The trees were carrying a moderate load of fruit. Most of them were about 15 years old with a limb spread of about 17 feet although some 7-year-old replants with a limb spread of 6 feet were present. Four trees, arranged in a square were irrigated, non-irrigated trees surrounding these being used as checks.

Nearly 500 gallons of water per tree was applied at each of three applications during midsummer, making a total of nearly 1500 gallons per tree. There was no trenching, the water merely being allowed to flow onto the ground near the trunk of each tree through a 4-inch hose from a tank mounted on a truck.

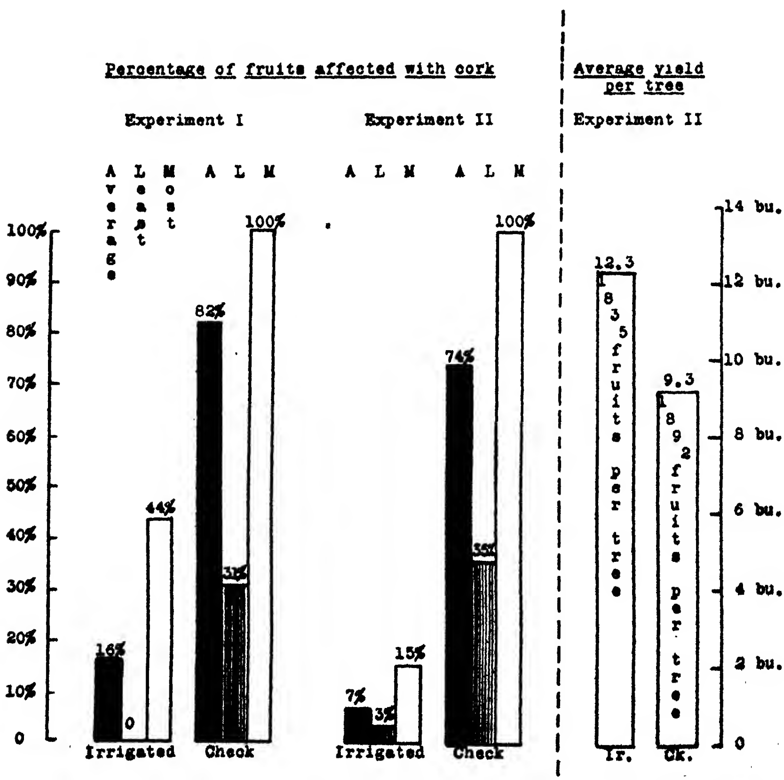

FIG. 2. Effect of irrigation on occurrence of cork and on size of McIntosh fruits.

At the time of taking the data, there was an average of possibly a bushel of drops per 15-year tree. For each tree, 25 random sample fruits from the ground and 15 from the tree were cut. No clear-cut difference in amount of cork between the picked fruits and the drops was apparent on these particular trees, though in some orchards a higher percentage of the drops was affected.

The average percentage of fruits affected for the four irrigated trees was 7 per cent. The range was from 3 to 15 per cent, all affected fruits showing only slight symptoms, many being in the water-soaked stage, not yet having become brown.

The corresponding average for 8 similar non-irrigated trees was 74 per cent, with a range of 35 to 100 per cent (see Fig. 2). The average for 6 similarly located non-irrigated McIntosh replants about 7 years old and just commencing to bear was 71 per cent with a range of from 35 to 100 per cent. In obtaining the results on these lightly loaded-replants, 10 drops and 10 picked fruits per tree were examined. There thus appears to have been no difference in amount of cork between the 7-year and the 15-year trees.

A water shortage was indicated also by size of fruits. One of the four irrigated trees was somewhat smaller, younger, and more lightly loaded than the other three, and was discarded in the consideration of size of fruits. Seven non-irrigated trees adjacent to those irrigated were used as checks.

The three irrigated trees averaged 150 apples per bushel, the range being from 148 to 152 as the average for the individual trees. The 7 non-irrigated trees averaged 205, the range being 181 to 219. The average total number of fruits per tree for the three irrigated trees was 1835 and for the non-irrigated 1892. The average yield of the irrigated trees was 12.3 bushels, and for the non-irrigated, 9.3 bushels. It is apparent that this increase in yield of the irrigated trees was a result of size of fruits, rather than number of fruits.

Discussion

It seems clear that irrigation in these tests decreased the amount of this form of cork as might have been anticipated from general observations contained in previous publications (1, 2, 3, 4). It also increased the size of fruits. It is not known whether the failure to get more nearly perfect control of cork was due to improper timing and distribution of water, or to the existence of some other etiological factor. In Experiment I, the irrigated tree showing the most cork (44 per cent) was one that developed a more extensive dying back of terminal twigs in 1932 than was the case with any other tree in the experiment. Another irrigated tree showing a large amount (25 per cent) was located on a slope, and was always watered from the lower side. The water did not get around well. All affected fruits were from the upper side. Both growers considered the treatments to have given commercially satisfactory control.

Probably the number of applications of water in Experiment I could have been reduced and the quantity per application increased without reducing the effectiveness of the treatment.

Somewhat different forms of cork occur. The author does not wish to imply that all forms would react to irrigation in the same way or even that this form would always react in the same way. It is conceivable that a water deficiency in the fruits could develop from various causes even with an adequate soil moisture supply or that the effect of the soil moisture deficiency could have been an indirect one, operating through modification of the soil solution.

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The Maintenance of Predetermined Soil-Moisture Conditions in Irrigation Experiments

By A. H. HENDRICKSON and F. J. VEIHMEYER, *University of California, Davis, Calif.*

INASMUCH as many important plant responses are determined by the presence or absence of readily available water, it is essential in irrigation experiments to have a clear understanding of the soil-moisture conditions. Many experiments have been carried on under the assumption that certain soil-moisture conditions have been maintained by the application of definite quantities of water at regular intervals, without taking into account the climatic conditions, the size of plant, the depth of rooting, or the water holding characteristics of the soil. It is the purpose of this paper to point out some of the soil-moisture conditions that can be secured and maintained, and some that cannot.

Generally speaking, in field experiments, in regions having rainless summers, there are three soil-moisture conditions that may be maintained. Rain, during the growing season, may be considered a factor that practically precludes the possibility of securing and maintaining soil-moisture conditions of a critical nature in irrigation experiments, unless it is kept from penetrating the soil. First, some soils may be kept saturated or nearly so, by frequent applications of large quantities of water; second, soils may be kept theoretically at about field capacity by the addition of enough water at frequent intervals to replace that lost by transpiration and surface evaporation; and third, soils may be maintained at or slightly below the permanent wilting percentage by not irrigating after the plants have used the readily available moisture provided by the winter rains. In addition to the above conditions, large or small fluctuations may be allowed to occur in the readily available supply, depending on the irrigation treatment. The first two conditions are not discussed in this paper.

Some workers still cling to the belief that certain definite soil-moisture contents between the field capacity and the permanent wilting percentage can be maintained by manipulation of the water, or by the use of certain devices designed to secure a uniform and rapid distribution of moisture. We have never been able to bring about a predetermined moisture content, between the field capacity and the permanent wilting percentage by the application of water to soils on which plants are growing, whether they be in containers or in the field, because of the limited movement of water by capillarity. Furthermore, because of the rapid use of water by plants, any preconceived moisture content between the field capacity and the permanent wilting percenatge cannot be maintained long enough to measurably influence growth or fruiting.

Reduction of soil moisture is brought about mainly by the extraction of water from the soil by plants. Moisture may be reduced to any desired content at or above the permanent wilting percentage

and, by watering at proper intervals, may be kept from going below the desired point. The widest range of soil-moisture fluctuation is that between the field capacity and the permanent wilting percentage. At each irrigation the soil-moisture content in the depth wetted is brought back to the field capacity. In other words, soils cannot be partially wetted, but must be wholly so or not at all.

A definite and practically unchanging moisture content cannot be secured until the plants have exhausted the readily available moisture. After the permanent wilting percentage has been reached (in some soils very slow extraction continues after this condition is reached), this moisture content can be maintained until the following wet season, or terminated, at will, by irrigation. Our irrigation experiments with deciduous fruits have shown that soil moisture is equally available to plants at all moisture contents from the field capacity to about

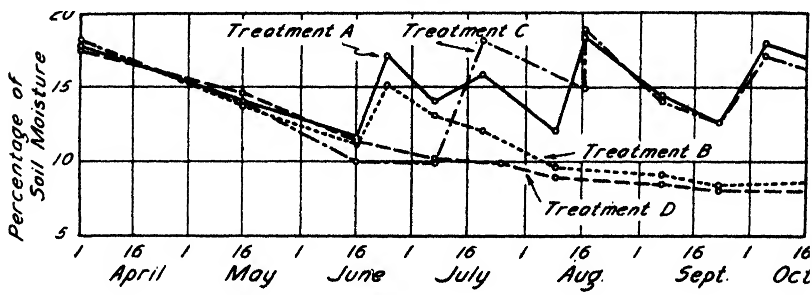

FIG. 1. Average soil-moisture conditions in the top 6 feet of soil in a mature prune orchard, where the basin system of irrigation was used.

the permanent wilting percentage. Hence, we may say that the important question in the maintenance of predetermined soil-moisture conditions is whether the supply of readily available water has been maintained or not.

The soil-moisture record given in Fig. 1 illustrates what we have been able to do with an orchard of mature prune trees at Davis, in the way of maintaining certain soil-moisture conditions. The record given was obtained in 1932 and is typical of those obtained in previous years. Similar records have also been obtained with other fruits. Each moisture content was obtained from the average of 10 samples from each treatment taken to a depth of 6 feet. Samples were also taken to a depth of 12 feet, but are not included in this paper because the growth and fruiting of the trees seemed to be influenced chiefly by the moisture in the top 6 feet of soil. Water was applied in carefully graded, square basins, each tree receiving the desired amount of water. The soil is a Yolo loam having a moisture equivalent of about 20 per cent in the top 3 feet, and of about 14.5 per cent in the 3- to 6-foot depth. The permanent wilting percentages are about 10 per cent and 9 per cent respectively. The samples for moisture determinations were taken in 3-foot increments, and the average moisture contents for 6 feet were used in making the chart.

The curves showing the rates of extraction from the first of April to between the middle of June and the first part of July are essentially straight lines, showing that the trees in each treatment used water at a uniform rate. From the data obtained in the first part of the season, it was possible to predict, fairly accurately when the readily available water would be exhausted. In the treatments (C and D) that were allowed to exhaust the readily available moisture as quickly as possible, the permanent wilting percentage was reached by C about June 16, and by D, about July 20. The trees in C are larger than those in D and used the water more rapidly. Treatment C was allowed to remain dry until July 11, after which it was kept above the permanent wilting percentage. Treatment D was not irrigated and stayed dry throughout the remainder of the growing season. Treatment B was given one irrigation on June 17. This treatment reached the permanent wilting percentage about August 9. It will be noted that in treatments B and D there was a very slow extraction of soil moisture after the permanent wilting percentage was reached. Treatment A was irrigated four times and kept above the permanent wilting percentage. The moisture in this treatment fluctuated between the field capacity and about 12 per cent.

Our experience indicates that, ordinarily in this orchard during the summer months, the readily available moisture resulting from an irrigation that wets the soil to a depth of 6 feet, is exhausted in about 6 weeks. From the facts that the readily available moisture from the winter rains is exhausted between the middle of June and the first part of July, and that an irrigation, wetting the soil to a depth of 6 feet, is used up in about 6 weeks, it will be seen that it is possible, by changing the dates of irrigating, to have the soil moisture reduced to the permanent wilting percentage, after about the middle of June, at nearly any desired period Furthermore, under conditions where the winter rainfall is less than it is at Davis, or where the evaporating conditions are more severe, or where the soil has lower water-holding properties, it should be possible not only to have the readily available soil moisture exhausted at approximately the same periods as at Davis, but also to have it exhausted much earlier in the season. In the latter case, studies could be made on the effect of soil-moisture conditions on the setting and early growth of the fruit. In any event, decisive differences in experimental treatments, such as are indicated in the chart are necessary to secure significant differences in responses of deciduous fruit trees.

The conditions under which these records were obtained were favorable for this type of an experiment. The soil was sufficiently uniform to give consistent results from year to year. On the other hand, irregular layers of gravel, of sand, or of clay often give soil-moisture results that are confusing and difficult to interpret. Soils of different textures vary widely in their water-holding properties, and composite samples, such as obtained with a soil tube crossing through two or more layers, may not be representative of the soil-moisture conditions of the plot as a whole. Under such circumstances, the number of samples necessary to properly interpret the soil-moisture condi-

tions would be so large as to be impractical. Furthermore, when gravel is intermingled with the soil, the difficulties in evaluating the results of sampling are almost insurmountable.

Another source of error in interpreting soil-moisture results, occurs when the entire soil mass occupied by roots is not wetted. One of

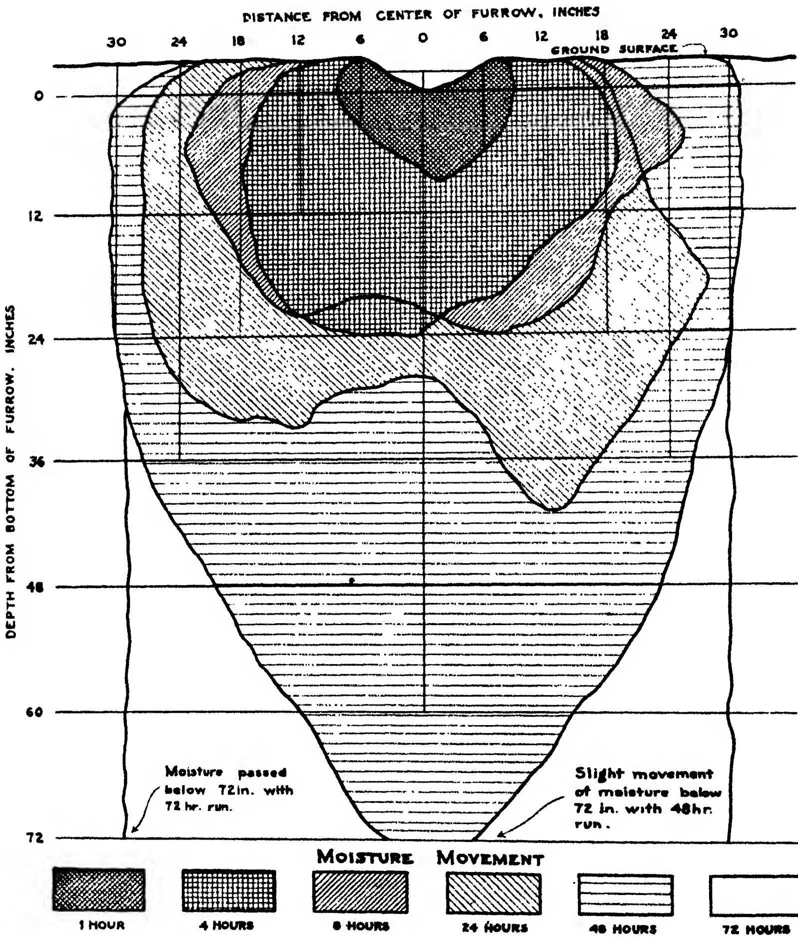

FIG. 2. Distribution of water from a furrow, after running water for different lengths of time.

the difficulties involved in the use of furrows for irrigating experimental orchard plots, is the uncertainty of wetting the entire soil mass to the desired depth. Water applied to the soil tends to move downward, with little lateral movement, unless the downward movement is impeded. Typical results from the distribution of water in furrows on Yolo loam are given in Fig. 2. The maximum lateral

movement was about 30 inches from the center of the furrow. The furrows must be close enough together so that the intervening spaces will be wetted, otherwise, samples may include the moist soil directly beneath, and dry soil from between the furrows. Furthermore, when furrows are used, they are often placed at a considerable distance from the tree. In this way a portion of the soil directly beneath the tree is dry except when moistened by rainfall. In such cases, while the average soil moisture may be above the permanent wilting percentage, there may be a considerable portion of the roots in soil that lacks readily available water. This portion of the roots in soil lacking readily available moisture may be large enough to influence the trees. Furthermore, if the amount of water applied is not sufficient to wet the entire plot to the desired depth, the inclusion of both dry and wet soil in the samples adds to the difficulties in interpreting the soil-moisture data. Obviously, averages obtained under such conditions do not indicate whether there is readily available soil moisture or not throughout the entire soil mass occupied by roots. In other words, a portion of the soil may have available moisture while the rest is maintained at the permanent wilting percentage. Because of these difficulties, we have applied definite quantities of water in carefully graded, square basins to insure wetting the soil throughout the plot to the desired depth.

Difficulty in attempts to maintain predetermined soil-moisture conditions is also encountered with young trees or with young annual plants, because the soil is not fully occupied by roots. This difficulty may also be encountered with mature trees in clay soils. Samples taken in the unoccupied portion of the soil may show a high moisture content, while those taken close to the plant may show a low one. Consequently, the average soil moisture content would be meaningless.

Interpretation of the results of soil-moisture investigations are always difficult, hence, experiments of this nature, designed to yield basic information should be carried out under the most favorable conditions as to topography, water supply, soil texture, and climate. A fairly uniform, gravel-free soil, preferably of medium texture in a region having a long rainless period during the growing season is essential for best results.

Orchard Trials of Nitrogen and Phosphorus

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ONE of the principal difficulties in testing the effect of phosphorus on tree performance has been the high fixing power of soils for this material, which prevents the tree from absorbing it. In an attempt to obviate this difficulty, an experiment was laid out in 1929 in which the fertilizer was applied in furrows deep enough to cut many small roots, instead of being broadcast or drilled in. The test was conducted about 4 miles from San Jose, California, by the Office of Horticultural Crops and Diseases of the U. S. Bureau of Plant Industry and the Division of Pomology of the University of California in cooperation with a Santa Clara Valley orchardist.

Blenheim apricots, Agen (French) prunes, and Lovell peaches growing on gravelly loam of the Yolo series were used. The soil is very deep, with no well-defined B horizon in the root zone, nearly level, and well drained. It is high in K but is only moderately well supplied with P.

The rainfall was light during the period of the experiment, averaging only 10.2 inches annually, most of which fell between November and April. Irrigation in the summer supplemented this supply, the square basin system being used. The trees were allowed to become wilted in the early fall each year.

The apricots and peaches were 18 years old when the experiment was started, the prunes, 16. The customary pruning practices of the district were employed. Very little pruning was given the prunes. The apricots and peaches were pruned severely, the annual growth being thinned and headed back to short stubs. Weak, injured, and crowding branches were removed. Since the peach trees had been interplanted with walnuts, it became necessary to cut back the peaches severely in 1932, at which time they were dropped from the experiment. Cultivation consisted of disking in the spring and after each irrigation.

The apricots and peaches were thinned each year, but the prunes were not thinned any year. This practice, no doubt, is a factor in the uniformity of yields of the first two fruits. In 1933 the apricot trees given ammonium sulfate set fruit more heavily than those not receiving it.

The treatments given were the same for all fruits, namely, ammonium sulfate in furrows, treble superphosphate and ammonium sulfate in furrows, phosphates in furrows and broadcast, manure in furrows and broadcast, manure and phosphate in furrows, and untreated checks. These treatments were all duplicated in the apricots except the broadcast phosphate treatment. Six check plots were used with each fruit. Neither broadcast treatment was duplicated with prunes or peaches. Ammonium sulfate was applied at the rate of 5 pounds per tree the first 2 years, and 3 pounds the last two. Phosphate

applications were at the rate of 8 pounds per tree per year, and manure about one-third cubic yard per tree per year. For furrow application, in the first 3 years two furrows were opened on each side of the tree with a plow to a depth of 5 to 6 inches. In the last year a disk plow and tractor opened a single furrow on each side of the tree about 8 inches deep. The materials were distributed along the bottom of these furrows, and the furrows filled.

Data were secured on tree circumference, yield of fruit, size of apricots, drying ratio of apricots (one season) and notes on the general appearance of the trees.

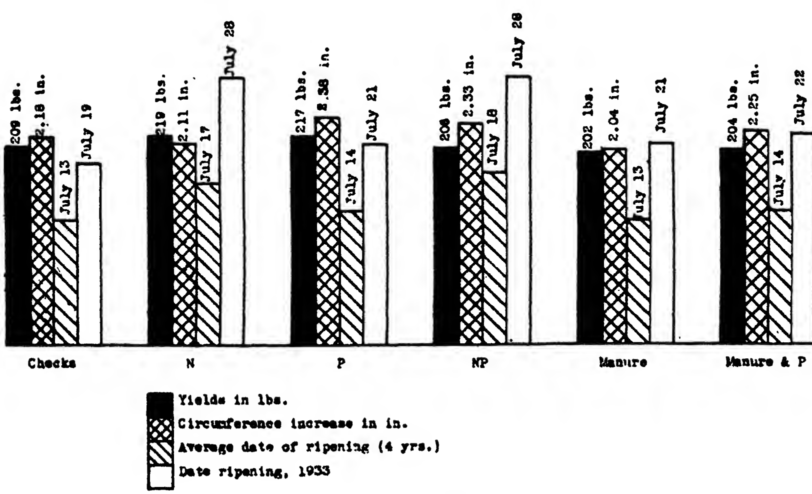

FIG. 1. Summary of yield, circumference increase and ripening date of figures for apricots.

At the time the work was begun the average size of the trees was remarkably uniform for each fruit. The fact that no plot of any species was significantly different in average circumference from any other plot of that species at any time during the experiment, and that the probable error of the mean was in most cases about 2 per cent of the mean, illustrates this point. The gain in circumference during the four seasons was also strikingly uniform, as shown for apricots in Fig. 1.

The yields also were uniform. There was no increase in yield in any plot due to the treatment. In the peaches and apricots this failure to respond may be partly due to the methods of pruning and thinning. The trees of these species made longer shoot growth and had more abundant foliage in the plots receiving N, but the severe pruning and thinning minimized the gains that would possibly have occurred otherwise. Fig. 1 shows the average yield per tree per year for the apricots. The prunes were more variable, one end of the block having a soil slightly different from the rest, but despite this,

and even in the absence of severe pruning and thinning, no fertilizer treatment has been effective in increasing yields.

The drying ratios obtained from the apricot plots are probably all within the range of sampling error. It is very difficult to bring all of the lots of fruit to the same moisture percentage when small samples are sun-dried. The 200-pound samples taken from each plot seemed unsatisfactory after one season's trial and this phase of the work was discontinued.

Nitrogen influenced the amount of shoot growth, abundance of foliage, color of leaves, time of leaf fall, and time of maturity of the fruit. The greater leaf area shaded the fruit more than was the case in the checks, with a resultant decrease in color development. Fig. 1 shows the date of mid-harvest, illustrating the delay in maturity caused by the nitrogen. The average date for the four seasons, and the date for 1933 are both given to show the accentuation of the effect. The dates of initial and final picking and the date of maximum picking not presented here, illustrate the same point.

Leaf samples, composed of the first full-sized leaf on shoots of 1 to 3 feet in length, were collected for analysis. Ten to 15 leaves from each of the trees in each plot were taken for each sample. Phosphorus and nitrogen were determined in these leaves.

TABLE I—N AND P CONTENT OF APRICOT AND PRUNE LEAVES MAY 25, 1933, AND PEACH LEAVES JUNE 2, 1932, IN PERCENTAGE OF DRY WEIGHT

Plot	Apricot			Prune			Peach		
	N	P	P/N	N	P	P/N	N	P	P/N
1 Nitrogen	3.39	.352	.104	2.61	.237	.091	2.40	.146	.061
2 Check	2.53	.461	.182	2.11	.328	.155	2.27	.189	.083
3 Nitrogen and phosphate	3.69	.339	.126	2.81	.244	115	2.65	.154	.058
4 Phosphate	2.71	.477	.176	2.11	.338	.160	2.37	.199	.084
5 Check	2.87	.415	.145	2.01	.328	.125	2.25	.191	.083
6 Manure and phosphate	2.97	.410	.138	2.13	.266	.163	2.23	.205	.092
7 Manure broadcast	2.64	.420	.159	2.11	.293	.139	—	—	—
8 Manure	2.68	.388	.145	2.19	.249	.114	2.05	.193	.094
9 Check	2.41	.438	.182	2.21	.277	.125	2.03	.183	.090
10 Check	2.64	.470	.178	2.17	.305	.140	—	—	—
11 Manure	2.92	.360	.123	2.25	.270	.120	2.41	.162	.067
12 Manure broadcast	2.67	.370	.138	—	—	—	—	—	—
13 Manure and phosphate	2.89	.339	.117	2.41	.286	.119	2.48	.175	.071
14 Check	2.62	.434	.166	2.17	.281	.130	2.27	.183	.081
15 Phosphate	2.77	.368	.133	2.27	.275	.121	2.19	.199	.091
16 Phosphate broadcast	2.75	.328	.119	2.31	.316	.137	—	—	—
17 Nitrogen and phosphate	3.83	.288	.075	2.46	.249	.101	2.45	.149	.061
18 Check	2.58	.374	.145	2.38	.271	.114	2.17	.160	.092
19 Nitrogen	3.37	.270	.080	2.65	.213	.080	2.57	.142	.061

Analyses of the leaves (Table 1) revealed a higher variability than had been anticipated. Though only the 1933 (May 25) data are

presented for prunes and apricots, they are representative of those obtained earlier. Since no samples of peach leaves were taken in 1933, the data for 1932 (June 3) are presented. The P content for a given season within a single treatment in some cases varied as much as 25 per cent of the mean. The N content, however, was more regular, the maximum range of variation being about 15 per cent, and several treatments showing a range of less than 5 per cent. It is, therefore, possible, that in some cases minor, but real, differences were passed over as due to normal variability. The plots receiving manure are cases in point. They are generally intermediate between the checks and the plots receiving N. It is probable that this is their true position, but due to the overlapping, it is doubtful whether this conclusion could be sustained from our data. There is, however, no doubt that the nitrogen content of the leaves is higher in the plots receiving $(NH_4)_2SO_4$ than elsewhere or that the phosphorus is lower in those plots. This result is similar to that reported for the apple by Larson (3). Kraybill's (2) results with tomato, also show low P with high N, and Emmert and Ball (1) show an inverse relationship between these elements with the same plant. In gooseberries grown on K-deficient soil, Wallace (7) shows no clear relationship between N and P, but here the effect of the K relationships apparently masks that of N. Thomas (6) shows lower P/N ratios in apple trees in tanks where N has been added. He finds a greater amount of P absorbed by these trees, however.

The P/N ratio is lower in every case where N has been added than in the plots not receiving N, whether P has been applied or not. Lilleland (4) has shown that a heavy crop reduced the P content of leaves. The effect of N in our experiments seems to overshadow the effect of the crop on the P content of the leaves. Because of the method of sampling, *i.e.*, a composite of all of the trees in the plot, this conclusion may be considered tentative. The percentage of N or of P in the leaves naturally varies in a given orchard because of many factors beyond the control of the experimentor, notably the soil, season of collection, crop, and season. In spite of these influences, the P/N ratio has been uniformly low where N has been applied. This is also the case in a series of trials reported by Proebsting (5). It is not certain that the same results would be obtained under other climatic and soil conditions.

Lilleland (4) has decreased absorption of N by peach trees in a soil low in P by large additions of P injected about the roots. This reciprocal relationship has not been applied in interpreting field behavior in fertilizer experiments. Interpretation of field data is greatly simplified in many cases if analytical data are available which show the fate of the materials added to the soil, and the need of following the fertilizer into the tree to determine whether or not it has been taken up is again emphasized.

It seems evident that adding the fertilizer in furrows, even though examination showed marked proliferation of roots in the region fertilized, has not caused a measurable increase in the P absorbed, and has not influenced tree behavior as regards growth and yield.

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A Chlorotic Condition of Plants in Arizona Related to Iron Deficiency

By A. H. Finch, D. W. Albert, and A. F. Kinnison,
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A MALADY of horticultural and ornamental plants, characterized by a chlorosis of the leaves, usually the topmost ones, has been commonly observed in Arizona.[1] In some plants the entire leaves are without chlorophyll, in others, some chlorophyll tends to remain along the leaf veins. Affected leaves are frequently smaller than healthy leaves and in some cases are curled or malformed. In apple a "rosette" of short shoots with chlorotic leaves may develop during mid-summer. A malformation of the entire top of eucalyptus trees well described as "frazzle top" occurs in severe cases. These symptoms may be followed by a burning and dying of the leaves. On old citrus trees a subsequent dying of the topmost shoots and of older branches is especially pronounced, providing a striking symptom of the malady and thereby tending to obscure the chlorosis.

Losses to growers have resulted from these chloroses and malformations. A citrus "decline" in the Salt River Valley and on the Yuma Mesa has perhaps caused the most serious loss, altho deciduous orchards, small fruits, and oramental plants have been seriously affected. A somewhat similar condition in pecan trees widely known as "pecan rosette" has already been reported.

The occurrence of these various symptoms has been generally attributed to climatic and environmental influences. Evidence of a specific cause for them has been lacking and efforts to correct the trouble thru adjusting cultural and irrigation practices have not been consistently or permanently successful.

In the present consideration of the problem, it was reasoned that such symptoms are the result of an internal condition in the plant, probably related to mineral nutrition and only secondarily related to environment. That similar symptoms and malformations are related to mineral deficiencies has been reported by various workers with different plants.

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[1]Since the preparation of this paper quantitative measurements of the iron content in healthy and affected citrus trees have been made. These, as many workers have reported for other plants, indicate that affected trees which respond to treatment with iron may contain as much or more iron than healthy green ones. Clearly the problem of citrus decline in Arizona is not one of a deficiency of iron in the soil or of a failure of iron to get into the tree. Rather, it appears to be one of maintaining available iron within the tree. Studies of hydrogen ion concentration of plant juices and of the reaction of the ash in healthy and affected trees are being made in an effort to gain information on the nature of iron fixation in the tissue. At the same time, field treatments, designed to lower the pH of the plant tissue and thereby increase the solubility or availability of iron in the tree, are being made. These latter include application of sulfur and sulfuric and other acids to the soil, injection of acids into the trees, shading of the trees and other treatments.

To ascertain if the present symptoms were related to a deficiency of certain ions, affected leaves were dipped in solutions of many different chemicals and in some cases the dry chemical was placed in holes bored in the tree trunk or in the soil at the base of the trunk.

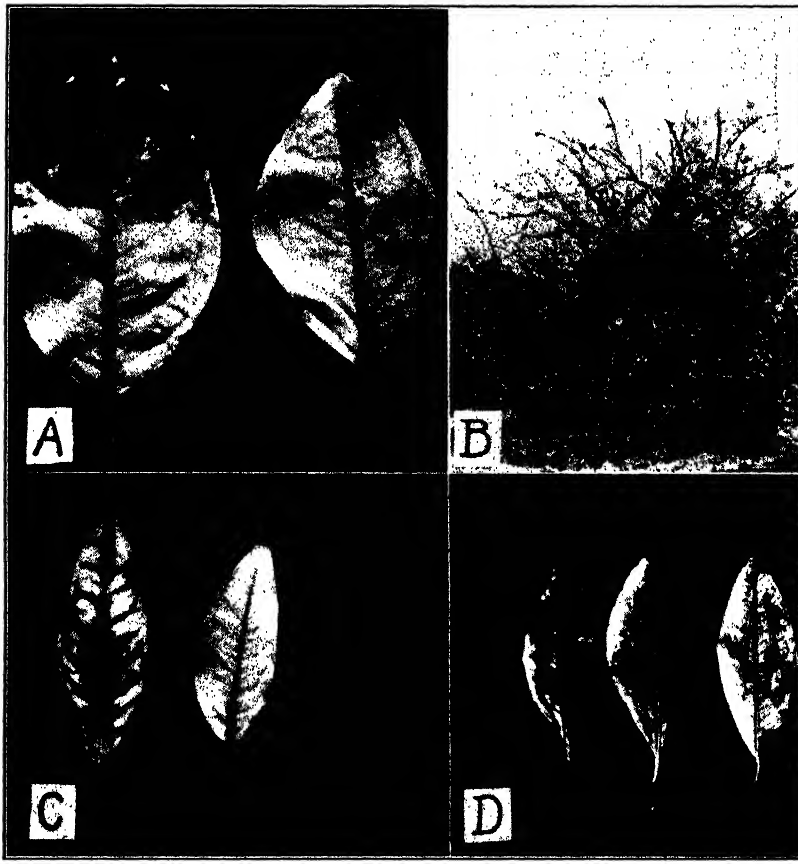

FIG. 1. A, leaves from an old chlorotic orange tree. Left, tip dipped in dilute ferric chloride solution; right, untreated. B, old chlorotic Valencia tree displaying characteristic symptoms of "decline." C, chlorotic orange leaves. Left, from a tree affected with "mottle leaf" which responds to treatment with zinc; right, from a "decline" tree which responds to iron. Note distinct difference in chlorotic pattern. D, old chlorotic lemon leaves, scratched with a knife and then dipped in .35 per cent ferrous sulfate solution. Greening occurred near the injury. Young leaves responded without previous injury to the surface.

Chlorotic plants of the following, some growing near Tucson, some in the Salt River Valley and some in the Yuma Valley and on the Yuma mesa, have responded to treatment with c.p. iron salts, namely, grapefruit, lemon, orange, sour orange, lime, tung-oil tree,

apple, pear, quince, plum, peach, cherry, apricot, pomegranate, strawberry, rose, lantana, pyracantha, jasmine, eucalyptus, pittosporum, red bud (*Cercis chinensis*), myrtle, vinca, zinnia, canna, Bermuda and Johnson grass, Japanese privet, cottonwood, and native Arizona ash.

Dipping chlorotic leaves in dilute solutions of ferrous sulfate or ferric chloride made up with distilled water and contained in a pyrex beaker was consistently followed by improvement of the leaves. On most of the plants old leaves did not become uniformly green but green spots appeared in 3 to 6 days after dipping, and repeated dipping increased the number and area of these spots. Young leaves tended to become more uniformly green. Leaves unfolding when dipped became entirely green and of normal shape and size. New growth and leaves formed after the dipping were again chlorotic. The use of a caseinate or a liquid glue spreader was found advantageous.

A greening of young chlorotic growth of eucalyptus trees could be noted in 10 to 15 days after placing ferrous sulfate or ferric citrate in the trunks. A pronounced improvement of the entire trees occurred in the course of 2 months. An equally striking but less immediate response followed the placing of 5 pounds of ferrous sulfate in the soil near the base of the trunk.

Trunk treatments made to citrus trees after the method of Thomas and Haas (1) have indicated that citrus trees do not respond as readily to such treatment as do some other trees. Orange trees so treated with ferric citrate in March, 1933, were definitely improved by October as compared to check untreated trees. Grapefruit trees treated in September showed some improvement 6 weeks later. Chlorotic lemon trees responded quite well showing definite improvement in 2 to 3 weeks following the placing of ferric citrate or ferrous sulfate in the trunk. Check untreated trees were not improved.

With all trees treated, those making some growth responded much more readily than those in which there was no new growth. Similarly, limbs making little or no growth were slow to respond whereas actively growing branches of the same tree responded readily.

Satisfactory commercial control has been obtained by spraying an iron solution on young grapefruit trees in the nursery at Tucson, and on young pear trees, strawberries, roses, quince, and pyracantha. Spraying experiments are being conducted at the present time on old severely affected orange and lemon trees on the Yuma mesa and in the Salt River Valley in an effort to induce healthy growth on these trees which respond so slowly to trunk and soil applications of iron

Recently, a chlorosis of citrus which seems not to yield to treatment with iron has been found in the Salt River Valley. The chlorotic pattern here is clearly different from that of the iron susceptible chlorotic leaves. This chlorosis yields to treatment with zinc and it is probably the "mottle leaf" reported by other workers. A few cases have been observed where a single orange tree was affected by both the iron and the zinc susceptible chloroses. There are many orchards in Arizona in which pecan trees affected with "rosette"

which yields readily to zinc (Annual Report, Arizona Agricultural Experiment Station, for the year ended June 30, 1932, et. seq.) are growing adjacent to citrus or deciduous trees affected with the iron susceptible chlorosis. It would seem that the mechanism for absorbing the different ions from the soil and transporting them to the leaves, or the need of the plant for them, may vary widely with different species. Of all trees observed, the eucalyptus seems most subject to the iron susceptible chlorosis and the pecan to the zinc chlorosis or "rosette."

The studies discussed herein are believed to indicate that an iron susceptible chlorosis is widespread in Arizona. They would seem to emphasize the need for information on the iron and zinc content and availability in Arizona soils and on the use, distribution, and movement of these ions in the plant. Further field experimentation on means of supplying iron to the plant is necessary.

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Influence of the Amount of Air Supplied to Apple Leaves Upon Their CO_2 Assimilation

By Everett P. Christopher, *Rhode Island State College, Kingston, R. I.*

INVESTIGATORS of the CO_2 assimilation of plants have used greatly varying supplies of air for a given leaf area, and have, almost universally, reported marked increases in assimilation associated with enriching the air with CO_2, (1, 2, 3, 4). In many cases, however, the assimilation, even with several times the CO_2 concentration of normal air, has been lower than that secured by Heinicke (5) where relatively large amounts of normal air were made available to each leaf. It may be that much experimental evidence on photosynthesis under natural conditions is open to criticism because of the use of unduly slow rates of air flow through the leaf chamber. Certainly plants are being subjected to very different conditions of CO_2 supply when 4.8 liters of air per hour are supplied to six clover plants by Wilson (4) and 50 to 100 liters per hour to one apple leaf by Heinicke (5).

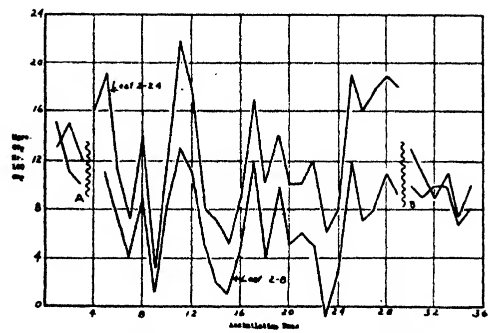


Fig. 1. Influence of increased air supply on CO_2 assimilation of leaves 2–24 and 2–8 Mar. 25 to Apr. 21, 1933. (Air to leaf 2–8 was 1.2 l. per cm^2 per hour. Air to leaf 2–24 was 1.0 l. before "A," 2.1 l. from "A" to "B" and 1.0 l. again after "B".)

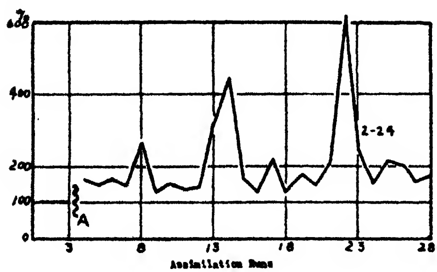


Fig. 2. Influence of increased air supply on CO_2 assimilation of leaves 2–24 and 2–8. (Expressed as result secured by dividing assimilation of leaf 2–24 over assimilation of leaf 2–8 before increasing air to leaf 2–24 by similar ratio after increase and multiplying by 100. Air supply to leaf 2–24 increased at "A" from 1.0 to 2.1 l. per cm^2 per hour.)

To obtain evidence on this question, studies using different rates of air flow were attempted, using the apparatus of Heinicke and Hoffman (6). Potted apple trees growing in a greenhouse were used for the first studies. Trees 2 and 4 were Baldwins and 1 and 3 were McIntosh. Leaf 2–8 was the eighth leaf from the base on Baldwin tree 2. Other leaves were similarly designated.

Leaves 2–8 and 2–24 were first compared. CO_2 assimilation was determined for 2- to 4-hour periods at different times of the day.

Leaf 2–8 received about 1.2 l. of air per cm^2 of leaf surface per hour during 34 runs. Leaf 2–24 received 1 l. per cm^2 per hour for 3 runs, 2 l. per cm^2 per hour for 25 runs and 1 l. per cm^2 for six runs. Fig. 1 graphically presents the assimilation of the two leaves. Though the daily fluctuations are very great, due to weather conditions, etc., during the first few runs, the assimilation curves are very similar. When the air flow to leaf 2–24 is doubled (A in Fig. 1) a very marked increase in CO_2 assimilation occurs. This increase is maintained throughout the 25 runs. When the air supply to leaf 2–24 is again reduced to 1 l. per cm^2 per hour (B in Fig. 1) the assimilation of both leaves becomes very similar.

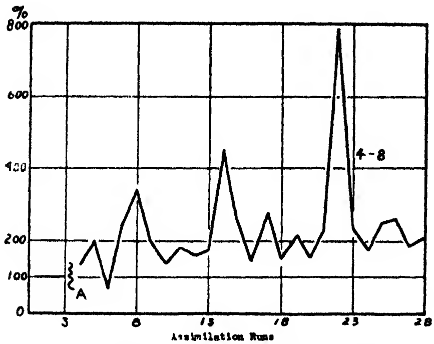


FIG. 3. Influence of increased air supply on CO_2 assimilation of leaves 4–8 and 2–8. (Expressed as result assimilation leaf 4–8 over assimilation leaf 2–8 before "A" divided by similar ratio after "A" times 100. Air increased from 1.2 to 2.4 l. per cm^2 per hour to leaf 4–8 at "A".)

To reduce the confusion caused by daily fluctuation in assimilation, Fig. 2 has been prepared. In this case the average of the ratios obtained by dividing the assimilation of leaf 2–24 by that of leaf 2–8 for the preliminary three runs is taken as 100 per cent. The ratio obtained after the air flow was increased, divided by the average preliminary ratio then becomes a curve fluctuating about a straight line which represents the ratio expected had the air flow remained constant to leaf 2–24 as it did to leaf 2–8. The irregularity of this curve suggests that factors affecting assimilation do not always bring about the same results for two leaves having different air flow rates.

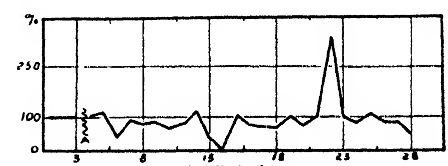


FIG. 4. Influence of decreased air supply on CO_2 assimilation of leaves 3–23 and 2–8. (Expressed as result secured by dividing assimilation leaf 3–23 over assimilation leaf 2–8 before air decrease by similar ratio after decrease of air to leaf 3–23 times 100. Air to leaf 3–23 reduced from 1.45 l. to 1.0 l. per cm^2 per hour at "A".)

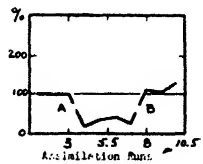
The air flow to leaf 4–8 was doubled at the same time as was that going to leaf 2–24. Fig. 3 gives the results obtained by comparing the assimilation of leaf 4–8 before and after air flow increase to that of leaf 2–8, which was maintained at a given air flow rate. It is interesting to note the similarity of the curves from leaves 2–24 and 4–8. The extremely high points may be explained by the very greatly reduced assimilation of the check leaf 2–8 when light and

temperature factors were unfavorable. Under such conditions the assimilation of leaves with a high rate of air flow is not reduced nearly as much as those with a low rate.

To determine whether reduction in the air flow rate would cause reduced assimilation, leaf 3–23 was given 1.45 l. of air per cm^2 per hour for four assimilation runs, and then was reduced to 1 l. Leaf 2–8 had 1.1 l. throughout the test. Fig. 4 shows the results. In most cases the assimilation rate of 3–23 tended to fall off but the reduction was not as pronounced as the rise secured by doubling the air to leaves 2–24 and 4–8.

To determine further the effect of reduced air flow on assimilation, leaf 4–8 was reduced from 1.2 l. to 0.2 l., then again given 1.2 l. per cm^2 per hour and compared with leaf 4–19 which was given 1.2 l. throughout the test period. Three, four and three runs were made respectively. Fig. 5 shows the results expressed as in Fig. 2. A very pronounced relationship between air supply and assimilation is shown.

Similar results were obtained with leaf 2–24 where the air flow was 1 l. per cm^2 per hour for 2 days, 0.1 l. for 4 days and then increased to 1 l. for 3 days. These results are shown in Fig. 6.



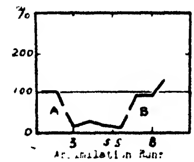


FIG. 5. Influence of decreased air supply on CO_2 assimilation of leaves 4–8 and 4–19. (Expressed as result secured by dividing assimilation leaf 4–8 over assimilation leaf 4–19 before decrease of air by similar ratio after decrease. Air to leaf 4–8 reduced from 1.2 l. to 0.2 l. per cm^2 per hour at "A" and increased to 1.2 l. at "B".)

FIG. 6. Influence of decreased air supply on CO_2 assimilation of leaves 2–24 and 4–19. (Expressed as result secured by dividing assimilation leaf 2–24 over assimilation leaf 4–19 before decreased air by similar ratio after decrease times 100. Air to leaf 2–24 reduced from 1.0 l. to 0.1 l. per cm^2 per hour at "A" and increased to 1.0 l. at "B".)

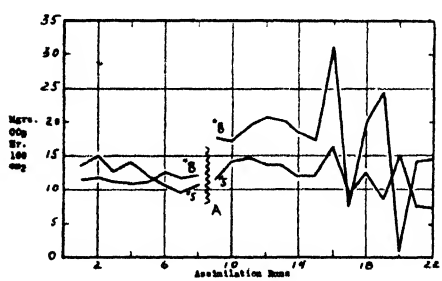


FIG. 7. Influence of increased air supply on CO_2 assimilation of leaves 8 and 5 on Baldwin (orchard conditions). (Air to leaf 8 increased from 1.0 l. to 4.0 l. per cm^2 per hour at "A".)

It is evident from these results that the amount of air supplied per cm^2 per hour has a marked influence on the rate of assimilation under the conditions of these experiments. It is fully as important to gauge air flow according to leaf area as it is to report assimilation in terms of mgrs. per 100 cm^2.

To test these results on mature trees under orchard conditions,

further series were run on leaves of Baldwin tree AJ 11 in the orchards of Cornell University, Ithaca, N. Y.

Leaves 8 and 5 were run 4- or 5-hour periods almost daily from July 8 to 25. A 5 day preliminary run was made supplying about 1 l. of air per cm² per hour to both leaves. At the end of five runs, the special air chamber designed by Heinicke (7) was fitted to leaf 8. The area of the cup was such that the air flow per cm² per hour was easily increased to about 4 l. The assimilation increased tremendously (88 per cent) showing that the supply of air previously available was not great enough for maximum assimilation. Fig. 7 shows the remarkable increase secured. Leaves 8 and 5 were both on the north side of the tree and, therefore, received indirect light most of the time.

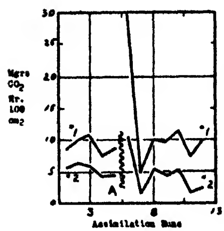


FIG. 8. Influence of increased air supply on CO_2 assimilation of leaves 1 and 2 on Baldwin (orchard conditions). (Air to leaf 1 increased from 1.6 l. to 5.0 l. per cm² per hour at "A".)

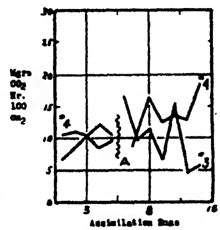


FIG. 9. Influence of increased air supply on CO_2 assimilation of leaves 3 and 4 on Baldwin (orchard conditions). (Air to leaf 4 increased from 1.4 l. to 4.5 l. per cm² per hour at "A".)

Leaves 1, 2, 3, 4, all on the south side of the tree were likewise paired and, after a preliminary run, leaves 1 and 4 given more air, using a modification of the air chamber used on leaf 8. Throughout the test, leaf 2 received about 1.5 l. air per cm² per hour. Leaf 1 started with 1.6 l. which was then increased to over 5.1. The increased assimilation (57.3 per cent) of leaf 1 was very marked (Fig. 8).

Leaf 3 received about 1.7 l. per cm² per hour throughout the run while the air flow to leaf 4 was increased from 1.4 l. to about 4.5 l. per cm² per hour. Again a marked increase (48.9 per cent) in assimilation by leaf 4 was observed (Fig. 9).

In leaf 8, where the preliminary air supply was only 1 l. per cm² per hour, the increase of assimilation was greater than in leaf 1 or leaf 4, where the preliminary air supply was 1.4 and 1.6 l., respectively.

DISCUSSION

It is evident that under the conditions of these experiments either increasing or decreasing the rate of air flow to a leaf tends to increase or decrease assimilation in the same direction. Assimilation rates much higher than those usually reported, even when CO_2 enriched air is used, have been consistently secured with normal air supplied at a rate somewhat faster than that usually employed. Experience with apple leaves suggests that an air flow of 2 to 2.5 l. per cm² per hour should be used in photosynthesis studies under natural conditions, if the CO_2 supply is to be about normal.

Acknowledgment

Dr. A. J. Heinicke suggested this study and has given valuable aid in all phases of the work.

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Temperature as a Factor Affecting Flowering of Plants

By H. C. Thompson, *Cornell University, Ithaca, N. Y.*

During the past several years the writer and some of his co-workers have carried on studies to determine the effects of various ecological factors on seeding of certain vegetable crop plants.

Of the various factors considered, temperature has had the greatest effect on type of growth, vegetative or reproductive, of most of the plants used in the studies. Among the studies on the effect of temperature on seeding made by the Department of Vegetable Crops, Cornell University, are those by Thompson (9) on celery, by Platenius (8) also on celery, by Miller (7) on cabbage, by Knott (5) on spinach, by Chroboczek (2) on beets, by Thompson (10) on onions grown from sets, and by Thompson and Knott (11) on lettuce. A brief summary of the results of these studies is presented in this paper.

Results of Studies with Celery

Experiments on celery were conducted both in the field and under somewhat controlled conditions in the greenhouse. Plants for the field experiments were started in a medium temperature (60 to 70 degrees F) greenhouse about the middle of February and were kept there until about April 1. At this time some of the plants were placed in a greenhouse where the temperature was held at 40 to 50 degrees F while others were held at medium temperature, as controls, until time for planting in the field. The plants were set in the field about the first of May and were given good culture throughout the season. Treatments were in duplicate and each room contained from 40 to 75 plants. The results for 3 years with two strains of a standard variety are given in Table I.

TABLE I—Effect of Exposure to Relatively Low Temperature (40 to 50 Degrees F) for 10, 20 and 30 Days on Subsequent Development of the Seed-Stalk in Celery

Preliminary Temperature Treatment	Number of Plants	Per cent Seed-Stalks
Check 60–70 degrees F	550	0.00
10 days 40–50 degrees F	550	7.63
20 days 40–50 degrees F	550	44.36
30 days 40–50 degrees F	550	74.00

The data in Table I show that the plants grown under medium temperature in the greenhouse until they were set in the field produced no seed-stalks. Those given 10 days at 40 to 50 degrees F produced an average of 7.63 per cent of seed-stalks; those with 20 days produced 44.36 per cent; and those with 30 days exposure to this temperature produced an average of 74 per cent of seed-stalks in the 3 years. There was variation in the percentage of seed-stalks produced in different years. For example, 30 days exposure to the

relatively low temperature resulted in 100 per cent of seed-stalks one year, 91.33 per cent in another year, and only 45.83 per cent in the third year. The variation is thought to result from difference in conditions prevailing in the field soon after planting. When the conditions are favorable for rapid growth for a few weeks following planting, the percentage of seed-stalks is much higher than when the conditions are not favorable for good growth.

Greenhouse experiments:—A large number of greenhouse experiments have been conducted during the past 10 years and all have given essentially the same results with reference to the effects of temperature on bolting. After the plants were given the preliminary treatments as previously described, they were divided into three lots for growth under three ranges of temperature, cool (50 to 60 degrees F), medium (60 to 70 degrees F), and warm (70 to 80 degrees F). Not all of the treatments were included in the warm house. Results of one of these experiments are given in Table II to illustrate the general trend. In this particular experiment the plants were put under the three temperature conditions November 16.

TABLE II—Effect of Exposure to Relatively Low Temperature for 15 and 30 Days on Subsequent Development of Seed-Stalks of Celery Under Three Ranges of Temperature

Preliminary Treatment	Number of Plants	Per cent of Seed-Stalks on Dates Given			
		March 20	April 3	April 25	May 8
In medium-temperature house					
Check 60–70 degrees F..	20	0.00	0.00	0.00	0.00
15 days 50–60 degrees F..	20	0.00	0.00	65.00	100.00
30 days 50–60 degrees F..	20	0.00	0.00	65.00	100.00
15 days 40–50 degrees F..	20	0.00	85.00	100.00	100.00
30 days 40–50 degrees F..	20	25.00	45.00	100.00	100.00
30 days 70–80 degrees F..	20	0.00	0.00	0.00	0.00
In cool house					
Check 60–70 degrees F..	20	0.00	0.00	100.00	100.00
15 days 50–60 degrees F..	20	5.00	65.00	100.00	100.00
30 days 50–60 degrees F..	20	10.00	60.00	100.00	100.00
15 days 40–50 degrees F..	20	88.00	100.00	100.00	100.00
30 days 40–50 degrees F..	20	80.00	100.00	100.00	100.00
In warm house					
Check 60–70 degrees F..	10	0.00	0.00	0.00	0.00
15 days 40–50 degrees F..	10	0.00	0.00	0.00	0.00
30 days 40–50 degrees F..	10	0.00	0.00	0.00	0.00

All of the plants that had been given preliminary low-temperature treatment, either 40 to 50 degrees F or 50 to 60 degrees F, went to seed in the medium-temperature house. The plants of the other two lots, that had no temperature treatment below the 60 to 70 degree range, did not produce a single seed-stalk. All of the plants grown, after the preliminary treatment, in the cool house went to seed, but the previous low-temperature treatment hastened seeding. In the

warm house, not a single plant went to seed regardless of the previous treatment. The high temperature seems to nullify the effect of the low-temperature treatment given previously. In a large number of experiments conducted by the writer, there has never been an instance of seed-stalk development in high temperature, except where they had started before the plants were subjected to the high temperature. After the stalks have started to develop, they elongate more rapidly in the high temperature (70 to 80 degrees F) than in a cool temperature (50 to 60 degrees F).

Attention should be called to the fact that heredity is involved in premature seeding. Some strains produce few seed-stalks even under the most favorable conditions, and some produce 100 per cent under the same conditions. But regardless of the heredity, no seed-stalks have been produced, in our experiments, unless the plants have been subjected to relatively low temperature. The experiments carried on entirely in the greenhouse show clearly the effects of temperature on type of growth—vegetative or reproductive.

Results of Studies with Cabbage

Two types of experiments were conducted with cabbage, one with young plants and the other with mature plants. Both types of experiments were carried on largely in the greenhouse, although one experiment on premature seeding was conducted in the field after the preliminary treatments were given.

Three experiments with young plants were conducted, two in the greenhouse and one in the field. The methods followed were similar to those discussed for celery, except that in the greenhouse experiments the cabbage plants were exposed to a lower temperature and for a much longer period than were the celery plants. In general, the results with cabbage plants were similar to those obtained with celery. The larger and older the plants were at the time of the temperature treatment, however, the greater was the percentage of seed-stalks.

Seed-stalk development in mature cabbage:—The first experiment with mature cabbage was carried on in the greenhouses during the fall and winter of 1925–26. Plants of a pure line of Danish Ballhead with mature heads were taken from the field on October 8 and 60 were potted immediately; 30 of these were placed in a medium-temperature greenhouse (60 to 70 degrees F) and 30 in a cool greenhouse (50 to 60 degrees F). Fifteen plants in each house were grown under the normal length of day and fifteen under the long day. The day length was increased by use of electric lights from 5 to 10 p. m. each day. The data are presented in Table III.

The plants in the medium-temperature house did not develop flower stalks but continued vegetative growth and each plant produced a second head on the elongated stalk. In the cool house, flower stalks emerged from the old heads and produced flowers in about 80 to 90 days. Increasing the length of day hastened slightly the production of the second head in the medium-temperature house and the emergence of the growing point of the plants in the cool

house. Flowering was not hastened materially by increasing the length of day. In an experiment with immature plants, increasing the length of day 5 hours by use of electric lights from November 15 to April 15 appeared to have a slightly depressing effect on seed-stalk development.

TABLE III—EFFECT OF TEMPERATURE AND LENGTH OF DAY ON TYPE OF GROWTH IN MATURE CABBAGE

Temperature and Length of Day	Number of Days for Growing Point to Emerge from Head	Number of Days to Flowering	Number of Days to Produce Second Head
Medium temperature			
Normal day........	50	Did not flower	150
Long day..........	49	Did not flower	140
Cool temperature			
Normal day........	76	154	—
Long day..........	62	152	—

Five of the plants in the medium-temperature house were kept until the fall of 1926 and these produced three heads each. In moving them to a new greenhouse four of the plants were broken, but the one remaining was kept in the medium-temperature house until the fall of 1927. This plant, during the 2 years, produced six heads and grew to a height of more than 8 feet. In the fall of 1927 it was moved to the cool greenhouse and by April 10, 1928, it had produced flowers.

Two experiments were conducted to determine the effect of a rest period at relatively low temperature on seed-stalk development. In the experiment previously discussed, no seed-stalks developed in the medium-temperature house. Some of the same lot of plants were given a rest period in storage at 40 degrees F for 2 months and these plants produced flowers in the medium-temperature house in 39 days. In the cool greenhouse, the plants produced flowers in 68 days after being given a rest period of 2 months. Rest periods of 15 days and 30 days at 40 degrees F were not very effective.

The marked effect of temperature on type of growth is shown in the results of an experiment on immature plants. By growing them at relatively low temperature, these plants went to seed without forming a head. After the seed had ripened, the seed stems were cut off and the stubs were planted in the garden on June 1. Normal axillary heads were produced and in the fall the plants were placed in cold storage at 40 degrees F for 2 months. They were then planted in the greenhouse where they produced a second crop of seed. The seed-stalk was again cut off after the seed had ripened and the stubs were planted in the garden as before. A second head was produced. Every plant in this lot of ten produced two crops of seed and two crops of heads in 2 years, but the normal order was reversed.

Results of Studies with Beets

Experiments were conducted with young and mature plants in the greenhouse and field to determine the effects of temperature and of length of photoperiod on seed-stalk development.

In general, the results of studies on premature seeding of beets were similar to those obtained in experiments with celery. However, beet plants required a longer exposure to relatively low temperature for subsequent seed-stalk development under medium temperature. The length of photoperiod is also an important factor in the development of the seed-stalk of the beet plant.

Beet plants grown continuously in a warm greenhouse (70 to 80 degrees F) under the normal length of day, from October to May, did not go to seed at all. Lengthening the day 5 hours by means of artificial light did not cause these plants to go to seed. Plants grown in a medium-temperature (60 to 70 degrees F) house developed a few seed-stalks under a day length of 15 hours. On the other hand, 100 per cent of the beet plants grown in the cool greenhouse (50 to 60 degrees F) produced seed-stalks under an 11-hour day. Even under an 8-hour day the plants grown in the cool house produced seed-stalks although they were barren. Increasing the length of day 5 hours in the medium-temperature house, increased slightly the percentage of seed-stalks. In the cool house, where all plants went to seed under the short day, increasing the length of day hastened seed-stalk formation by several weeks. After the seed-stalk had started to develop, it grew much more rapidly in the medium, or in the warm house, than in the cool house, but if the plants were kept too long at high temperature the seed-stalk became vegetative.

Effect of exposure to relatively low temperature on subsequent seeding:—Beet plants were exposed for varying lengths of time to relatively low temperature (40 to 50 degrees F) to determine the effects of this range of temperature on subsequent seeding at higher temperatures. The effects of exposing plants to relatively low temperature varied considerably, depending on the temperature and the photoperiod under which they were grown subsequently. For example, plants grown for 30 days at 40 to 50 degrees F and then grown in a warm house did not produce any seed-stalks under either short- or long-day conditions. The warm temperature seems to nullify the effect produced by the previous low-temperature treatment. The combination of medium temperature and short day also nullified the effects of the low-temperature treatment given previously. Plants grown under medium-temperature and long-day conditions produced a considerable percentage of seed-stalks. The low temperature treatment hastened seeding of plants grown subsequently in the cool house, but all plants in the cool house went to seed.

As mentioned above, 30 days' exposure to relatively low temperature was not sufficient to cause seeding in the warm house, even under a long photoperiod. Lengthening the cold treatment to 60 days resulted in some seeding in the warm house, but even 90 days of exposure to the cold treatment did not bring all of the plants to flowering when they were grown subsequently at a high temperature.

Experimental results with full-grown beet plants were similar to those with seedlings. When full-grown plants were grown in the cool greenhouse (50 to 60 degrees F) they went to seed under the short, medium, or long day, but the lengthening of the day hastened seeding. In the medium and warm greenhouses the plants did not develop seed-stalks under either the normal or long day, but developed a second and a third enlargement above the original one. Some of the plants which did not go to seed in the third year of their growth were transferred to the cool house in the fall of 1931 and by January 12, 1932, seed-stalks began to appear. By March 5, blossoms were in evidence. These plants were kept growing continuously and developed new shoots from the axils of the leaves on the main axis. Flowers were produced on these shoots in July.

Seed-stalks frequently start to develop but, owing to unfavorable conditions such as high temperature, they do not produce flowers but a rosette of leaves at the top of the stalk. If such plants are grown subsequently in a medium or warm house, an enlargement develops at the top of the stalk. This enlargement has the appearance of a normal beet root and may develop to very large size (5½ inches in one instance). If plants with barren stalks are grown subsequently in cool temperature, new seed-stalks develop from the top of the one previously formed. Even plants which have developed normal seed-stalks will produce a second crop of seed when grown under favorable conditions. In fact, the type of growth can be changed several times by changing the environment.

Results of Studies with Onions

Onions grown from sets frequently develop seed-stalks within a few weeks after planting and such plants seldom, if ever, produce marketable bulbs. Experimental results obtained by the writer indicate that under ordinary field conditions only the large sets, ¾-inch in diameter or larger, produce any considerable percentage of seeders. No experiments have been conducted to determine the effects of growing temperature on seeding but studies have been made on the effects of storage temperature on seed-stalk development in the field. Sets have been stored in cold storage at 30, 32, 40 and 50 degrees F and in common storage at 50 to 60 and 60 to 70 degrees F. There was some seed-stalk development at all temperatures except at 60 to 70 degrees F. The 40-degree storage resulted in the largest percentage and the earliest development of seeders; followed by the 50- and 32-degree temperatures. Sets stored at 30 degrees F produced few stalks and this is considered the best temperature of those used for the storage of sets. In common storage at relatively high temperatures, the sets dry out; in cold storage at 40 to 50 degrees F, the sets sprout.

Results of Studies with Spinach

Spinach plants of the Virginia Savoy and Old Dominion varieties exposed to 40 to 50, 50 to 60, 60 to 70, and 70 to 80 degrees F for 30 days when grown under a long day (15 hours) go to seed in the following order: 60 to 70, 50 to 60, 70 to 80, and 40 to 50 degrees F.

This order is the same whether the plants are grown subsequently at 50 to 60, 60 to 70, or 70 to 80 degrees F. In other words, both the very high and the very low temperature during the early stage of growth delay seed-stalk development in spinach plants grown under long-day conditions. The seed-stalks appear first in the 70 to 80 degree house, then in the 60 to 70 and last in the 50 to 60 degree F.

When the plants are grown under a short photoperiod, the 30-day low-temperature treatment is effective in hastening seed-stalk development, the order of seed-stalk appearance being 40 to 50, 50 to 60, 60 to 70, and 70 to 80 degrees F. Following the preliminary treatment the order of seed-stalk development under the three ranges of growing temperature is 70 to 80, 60 to 70, and 50 to 60 degrees F. Seed-stalks developed at 70 to 80 and 60 to 70 degrees F when the day length was less than 11 hours and at 50 to 60 degrees F when the photoperiod was 12 hours.

Results of Studies with Lettuce

Preliminary studies indicate that high temperature (70 to 80 degrees F) prevents head formation and materially hastens seeding. Seed stalks developed a month earlier at 70 to 80 degrees than at 60 to 70 degrees F. At 70 to 80 degrees F lettuce plants went to seed under a short day (10 to 12 hours). A temperature range of 60 to 70 degrees F was most satisfactory for head formation. Heading took place about a month later in the 50 to 60 degree house than in the 60 to 70 degree house. Increasing the length of day increased the size of the heads in the cool greenhouse.

A report on this study is given by Thompson and Knott in another paper at this meeting.

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The Effect of Certain Truck Crops on the Yield of Truck Crops Following Them on the Same Plots in the Next Season[1]

By WARREN B. MACK, GERALD J. STOUT, and FRANK W. HALLER, *Pennsylvania State College, State College, Pa.*

THE field experiments of which some of the results are reported in this paper were begun in 1928 and were continued for five consecutive seasons. It is considered advisable to summarize them at this time, even though the results are inconclusive in some respects, because of the fact that circumstances made it necessary to discontinue the experiments at the end of the 1932 season.

The soil of the experiment is Hagerstown silt loam, which is well drained, fairly uniform in superficial physical characteristics, and productive. Before being placed under experiment it was used for the growing of general farm crops in the usual four-year rotation of corn, oats, wheat, and hay. The acidity varied from approximately pH 6.1 to 7.0; that of most plots was about pH 6.3 to 6.7. The topography was somewhat variable; part of the area, including three tiers of plots, was nearly level, and the remainder sloped toward the southeast (Fig. 1).

The experimental area was divided into nine tiers, each containing nine plots of which the dimensions were 24 x 60.5 feet. The longer dimensions of the plots were crosswise of the tiers. An area 3 feet wide, along each of the longer borders of the different plots, served as a guard strip; these strips were occupied by the same crop as that on the respective plots, but yields were not recorded. The area of each plot from which yields were measured, therefore, was 18 x 60.5 feet, or exactly one-fortieth acre. The different tiers of plots were separated by roadways 7 feet wide. The tiers were numbered consecutively from south to north, and the plots from west to east. Each plot could therefore be designated by its tier and plot numbers.

Nine different truck crops were grown in each season; early cabbage, onions, sweet corn, stringless beans, potatoes, tomatoes, summer pumpkins, carrots, and late cabbage. Each crop occupied an entire tier in the odd-numbered years, and the same numbered plots in all tiers in the even-numbered years. The tiers or plots occupied by a given crop were rotated, so that the crop which occupied tier 1 in 1929 occupied all plots 1 in 1930, tier 2 in 1931, and all plots 2 in 1932, and so on; that on tier 9 in 1929 and plots 9 in 1930, of course, occupied tier 1 in 1931 and plots 1 in 1932. In this way, each crop followed itself and each of the other crops in each year after the first, and would have done so on every plot of the area if the experiment had been continued long enough for a rotation to be complete. A cover crop of rye and winter vetch was planted on each plot as soon as practicable after the truck crop grown on it was harvested. Because

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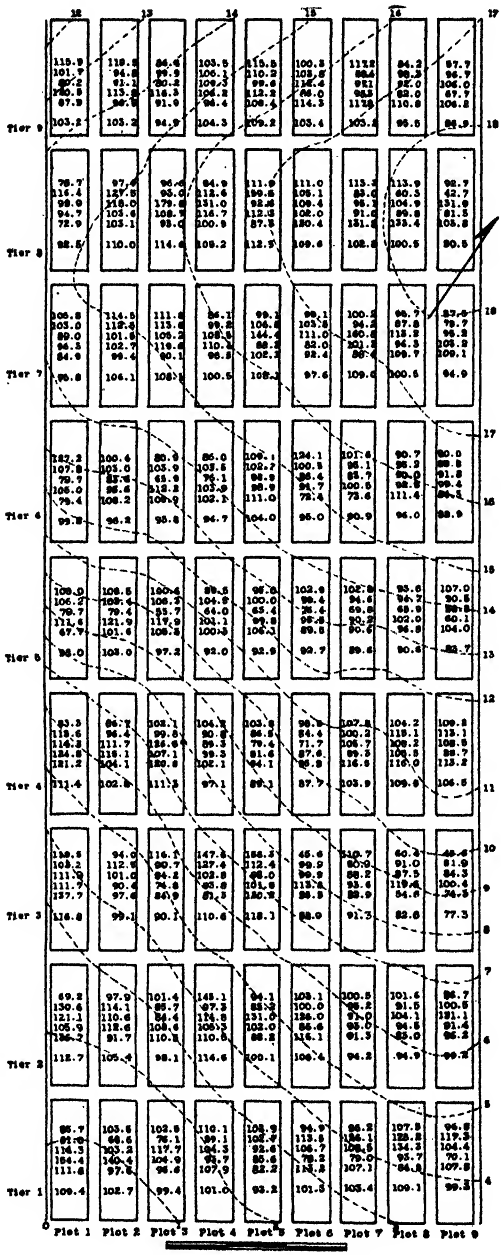

FIG. 1. Map of experimental area, with 1-foot contour lines. Numerical data on each plot are the annual yield indices for 1928 to 1932, and the average index for the five seasons of the experiment, in order from top to bottom.

all crops were not harvested at the same time, different amounts of cover crop were produced after the different crops; such differences might conceivably have influenced succeeding crops. All crops were fertilized at the rate of 40 pounds per acre of nitrogen, 120 pounds of phosphoric acid, and 40 pounds of potash from nitrate of soda, superphosphate, and muriate of potash, respectively.

The first crops were grown in 1928. Very frequent showers during June and July made cultivations and weed control practically impossible, so that late crops were very unsatisfactory, and for this reason the area was replanted in the same way in 1929. Results in 1928 with different cover crops indicated that these complicated the experiment unduly, and thereafter the plots were treated uniformly in this respect.

Records included the weights in pounds of the marketable portion of each crop for each plot; the dates of plowing, fertilizing, planting, and harvesting of the truck crops, and of plowing and seeding for the cover crops; and estimates of the green and dry weights of crop residues where considerable quantities of residues were left, and the amounts thereof could be estimated satisfactorily.

Particular attention will be paid in this report to the yields of the crops with reference to the truck crops which preceded them, and to certain other conditions which appear to have influenced their yields. In order to relate the yields of one crop to those of the other, or the yields in one season with those in another, all plot yields are stated in terms of indices which are the percentages of the average yields for all plots of the respective crops, in the given season. For example, the average yield of early cabbage on the nine plots of tier 1 in 1928 was 636.7 pounds, and the yield on plot 1 was 545.8 pounds. The yield index for plot 1, therefore, was 545.8/636.7 x 100 or 85.7. These indices are shown in Fig. 1, which is a map of the experimental area, in which the yield indices for the different crops in the five seasons, together with the average index for each plot, are tabulated in chronological order from top to bottom, the bottom figure on each plot being the average for that plot.

The average yields in pounds per plot, from which these indices were computed, are shown in Table I. The actual yield of the crop on any particular plot may be calculated, of course, by multiplying

TABLE I—Average Yields of Marketable Portions in Pounds per Plot (1/40 Acre)

	Early Cabbage	Onions	Sweet Corn	Beans	Potatoes	Tomatoes	Summer Pumpkins	Carrots	Late Cabbage
1928	636.7	57.2	14.9	76.0*	173.7	424.1	420.0	306.3	227.2
1929	499.7	349.1	94.3	143.0	139.7	323.7	131.7	290.3	377.5
1930	526.6	339.1	51.9	50.6	112.7	318.9	230.8	241.2	316.2*
1931	606.2	417.1	155.9	79.9	181.0	599.9	329.5	496.7	258.3
1932	474.0	365.6	167.0	73.6	251.0	244.0	190.5	481.0	460.0

*Weight of entire plants.

the average yield for that crop for the given season (shown in Table I) by the index of the plot in that season (shown in Fig. 1) and dividing the result by 100.

It may be observed that the indices for many of the plots (Fig. 1) are variable from year to year, although the average indices of certain plots for the five seasons are considerably higher than those of other plots. In the southern corner of the area and in tiers 7 and 8, a considerable number of the plots have average indices above 100, while in an irregularly shaped area between tier 2, plots 7, 8, and 9, and tier 6, plots 3 and 4, most of the plots have low average indices. In general, the more level areas have high indices and the more sloping areas, low indices. The values are not consistently high or low, however, except on a very few plots; even on the plots with the least two average indices, plots 8 and 9 in tier 3, there is one index on each which is 100 or above. Correlations among indices for the same plots in successive seasons are surprisingly small, though they are positive in all cases. The correlation among plot indices in 1928 and 1929 is $+ 0.280 \pm .0076$; in 1929 and 1930, $+ 0.408 \pm .0070$; in 1930 and 1931, $+ 0.287 \pm .0077$; and in 1931 and 1932, $+ 0.300 \pm .0076$. The correlation among plot indices in 1929 and average indices for the same plots for 1930, 1931, and 1932 is $+ 0.300 \pm .0076$.

These facts indicate that certain characteristics of the plots exert a small but significant influence in determining the crop indices; they suggest also that certain other conditions cause the yield indices to vary considerably in many instances.

The relations among the different crops with reference to the variations in yield indices of succeeding crops is shown in Table II, which contains the average yield indices of all crops following each crop, for each annual succession. An example will be sufficient to show how these average yield indices were computed from the plot yield indices in Fig. 1. Indices for all plots of tier 1 in 1930 (the third index from the top of the column on each plot) were averaged and tabulated as the average index of all crops following early cabbage, the crop which occupied tier 1 in 1929. In this table, as in Fig. 1, certain differences are clearly evident, though these differences are not consistent from season to season. In 1930, for example, the average yield indices of crops following early cabbage, onions, summer pumpkins, and carrots are significantly greater than those of crops following sweet corn, potatoes, and tomatoes, the probabilities in each case being less than 1 in 30; crops following potatoes and tomatoes are significantly poorer than those following the other crops. In 1931, crops following sweet corn, onions, beans, and early cabbage are better than those following tomatoes and pumpkins, while crops following late cabbage are poorer than those following other crops except tomatoes and pumpkins. Differences are apparent also in 1932, but none are specially significant as shown by the fact that the probabilities in all cases are greater than 1 in 20.

The most satisfactory records of crop residues were obtained in 1929. The correlation among the green weight of the crop residues

on the different plots, estimated from the weight of certain samples on each plot, and the yield indices of the crops on the respective plots in 1930, was $+ 0.195 \pm .010$, which is considerably less than the correlation among crop indices on the same plots in the same two seasons. It is evident, therefore, that crop residues exerted little influence on the succeeding crops in this experiment.

TABLE II—The Influence of Different Crops on the Average Yield Index of the Crops Which Follow Them in the Next Season

	Early Cabbage	Onions	Sweet Corn	Beans	Potatoes	Tomatoes	Summer Pumpkins	Carrots	Late Cabbage
1930	109.6	111.6	95.3	101.7	67.9	84.0	114.3	118.1	97.5
1931	113.9	110.7	107.8	103.4	98.1	91.5	92.6	97.4	84.7
1932	102.7	91.0	109.3	95.8	94.3	97.2	105.4	103.4	100.9
Average	108.7	104.4	104.1	100.3	86.8	90.9	104.1	106.3	94.4

In brief, the yields of crops were better after certain crops than they were after others, but relatively favorable or unfavorable influence was not exerted by the same crops in the different seasons. This inconsistency suggests that the differences probably resulted from conditions other than the effect on the soil of the particular crops in question, though the influential conditions undoubtedly were associated with the culture of these crops. It is quite possible that the differences were due to the physical condition of the soil at the time when certain cultural operations were performed, such as plowing, harrowing, harvesting, preparation of the soil for cover crop seeding, or from differences in the amount of cover crop grown. Whatever the causes, it is apparent that differences in conditions affecting crop production were present, originating with the culture of certain crops, and persisting during the following season; these temporary differences were more influential than the more permanent characteristics of the plots, topography for example.

The Effect of Soil Conditions on the Growth and Composition of Certain Vegetable Crop Plants as Influenced by Soil Reaction

By M. M. Parker, J. B. Hester and R. L. Carolus, *Virginia Truck Experiment Station, Norfolk, Va.*

An experiment was conducted at the Virginia Truck Experiment Station for the purpose of ascertaining the optimum pH range for best growth of cabbage, radishes, small and large seeded lima beans, garden peas and black-eyed peas. In connection with the productivity records determinations were made on the effect of the various soil reactions upon the chemical composition of the plant and upon the soil solution.

Plat Technique

The area selected represented a well-drained level, comparatively fertile Norfolk sandy loam, with a pH value of approximately 4.8. In order to increase the acidity the entire area was given a uniform application of ammonium sulfate at the rate of 1 ton to the acre during July, 1931. It was then divided into seven plats 58 feet long by 17 feet wide, replicated twice. During December the plats were treated with the following amounts of hydrated lime to the acre: No lime, 1,323 pounds, 2,646 pounds, 3,969 pounds, 5,292 pounds, 6,615 pounds, and 10,584 pounds. This gave the following series of soil pH readings: 4.4, 5.0, 5.5, 5.9, 6.2, 6.4, and 7.0.

The resultant changes in the soil reaction (Fig. 1) brought about certain variations in the soil phenomena. The solubility of phosphorus was influenced to the extent that the maximum amount became water soluble between pH 5.5 and pH 6.5 and the minimum at the lowest reaction. Toxic aluminum came into solution at pH values below 5.0 with the most acid reaction giving the greatest concentration. The replaceable calcium varied with the applications, but the water soluble did not increase proportionately to the amounts added. There was a slight difference in the replaceable magnesium with the greatest quantity appearing at pH 6.6 The variations in available potash were not significant.

The amphoteric behavior shown by soil colloids is due to the fact that these complexes represent salts of weak acids (silicic, humic, etc.) and bases (aluminum, iron, etc.). These acids and bases only partially neutralize each other, thereby leaving free valences. These free valences account for the base exchange capacity of a soil at high pH values and for the adsorption of phosphates, etc. at low pH values. The amphoteric point of a soil colloid (the point of completely hydrogen and hydroxyl saturated colloids) varies with the chemical composition of the soil colloid. The amphoteric point of this soil colloid in a normal solution of Na_2SO_4 is pH 4.6 This means that as the pH of the soil approaches 4.6 and below, aluminum ionizes and becomes

soluble. As the aluminum ionizes the soluble P_2O_5 is precipitated as an insoluble aluminum phosphate. The data in Fig. 1 indicate that the water soluble P_2O_5 is at a maximum at about pH 6.0 (about 40 per cent CaO saturation); below this pH value aluminum begins to ionize and the phosphorus is precipitated, above this pH value the calcium in solution increases enough to form tricalcium phosphate.

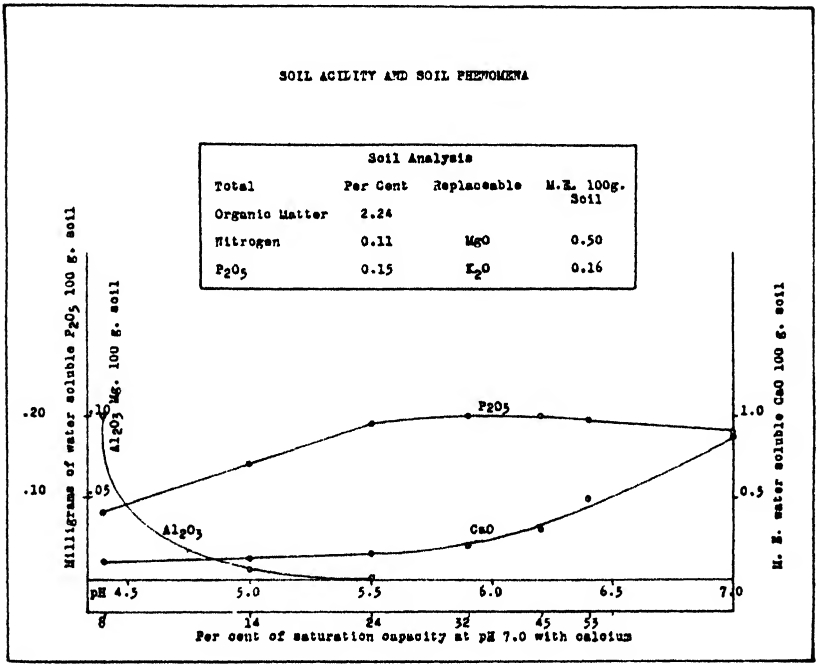

FIG. 1. Soil acidity and soil phenomena.

A marked difference in the biological activity of the soil was noted. Under controlled laboratory conditions the following amount of organic matter (carbon x 1.7) as carbon dioxide was liberated from 100 grams of soil over a period of 20 days at optimum moisture content:

Mean pH	4.4	5.0	5.5	5.9	6.2	6.4	7.0
Milligrams organic matter liberated	9.5	18.9	20.4	22.1	25.0	17.8	13.6

These data indicate that the biological activity has a trend similar to that of the solubility curve of phosphorus. Although the total biological activity was impaired by a reaction of pH 4.4 nitrates were formed in that soil about as readily as at the other pH values.

Crop Yields

Standard fertilization and cultivation practices were employed in growing the crops. Due to a deficiency of rainfall, conditions were not ideal for growing some of the crops and yields in these cases were extremely low, markedly accentuating the effects of soil acidity. Care was taken to obtain a uniform stand of plants, and a normal growth by thinning out the plantings of radishes, peas, and beans. One row of each vegetable was planted in a plat; and the rows were spaced approximately 3 feet apart.

The yields at the various reactions are expressed as the per cent decrease from the yield obtained at the optimum pH reaction. Of all of the vegetables grown, black-eyed peas and radishes were apparently the least susceptible to injury at pH 4.4, showing only 30 and 45 per cent decreases. These were followed successively by small seeded limas with 65 per cent decrease, cabbage 78 per cent, and garden peas and large seeded limas 85 per cent.

At reactions below pH 5.5 all of the vegetables showed marked decreases in growth and yield. At this reaction nodule formation became evident on the garden peas and all plants appeared normal. Radishes were only 5 per cent below the optimum and the other vegetables, with the exception of large seeded lima beans and peas were approximately 20 per cent below optimum. At pH 5.9 only garden peas and large seeded lima beans were considerably below normal and at higher reactions the optimum growth was obtained for all vegetables. The preliminary results indicated that optimum yields were obtained at the following soil reactions: Radishes pH 6.2 and 7.0, cabbage 6.4, garden peas 6.2, small seeded limas 7.0, large seeded limas 6.4, and black-eyed peas 5.9 and 6.2. (See Table I).

TABLE I—Per Cent Decrease Below Optimum Yield

Mean pH	Blackeyed Peas (1)*	Radishes (2)	Small Seeded Lima Beans (2)	Cabbage (2)	Large Seeded Lima Beans (1)	Garden Peas (1)
4.4	30.0	45.0	65.5	78.3	85.8	85.9
5.0	20.0	13.1	41.5	32.4	40.7	50.0
5.5	20.0	5.2	20.1	17.8	37.5	22.7
5.9	0.0	8.2	12.9	5.4	24.1	22.7
6.2	0.0	0.2	7.1	5.4	11.2	0.0
6.4	10.0	1.4	11.0	0.0	0.0	13.6
7.0	10.0	0.0	0.0	4.3	9.6	9.0

*( ) Number of seasons.

Plant Composition

Dried foliage material of cabbage, garden peas, and large seeded type lima beans, taken at the time of maturity from plats of the different pH values was analyzed to determine the possible relationship existing between the chemical composition, plant growth, and soil reaction. To adequately portray the conditions existing in the plant the results are given on the basis of the per cent of the dry weight

of the plant in Table II and on the basis of the amount in terms of milligrams of the various elements in a single plant in Table III. In the table in which the figures are on a percentage basis, only fluctuations of the various minerals, on the basis of equal portions of dry weight are compared. However, a comparison as shown in the table that evaluates growth, considers the total amount of each material removed from the soil by the plant and aids in a more comprehensive visualization of the existing conditions.

TABLE II—THE EFFECTS OF THE SOIL REACTION ON PLANT COMPOSITION* (EXPRESSED IN PER CENT DRY WEIGHT)

Soil Reaction	Average Green Weight per Plant Grams	Dry Wt. Per cent	N Per cent	P Per cent	K_2O Per cent	CaO Per cent	MgO Per cent	Fe Per cent	Total Ash Per cent
				A. Cabbage					
pH									
4.4	115	10.80	5.05	.513	5.72	4.42	.407	.017	16.50
5.0	189	10.50	4.72	.538	4.78	6.38	.544	.013	17.50
5.5	315	7.58	3.84	.545	5.20	7.50	.532	.017	18.50
5.9	335	9.25	4.18	.586	4.83	7.53	.568	.018	17.50
6.2	288	8.81	3.79	.567	4.98	6.92	.480	.013	16.75
6.4	393	8.91	3.48	.582	4.88	6.59	.400	.013	15.60
7.0	379	6.57	3.85	.703	5.59	7.40	.480	.014	19.30
				B. Garden Peas					
4.4	2.15	34.6	3.15	.183	3,42	6.78	.856	.101	21.47
5.0	6.07	30.3	2.06	.120	3.45	9.58	.628	.060	20.78
5.5	15.80	28.5	1.57	.194	2.41	8.88	.516	.050	18.63
5.9	18.20	28.9	1.55	.205	2.23	8.70	.359	.044	17.91
6.2	19.10	27.1	1.35	.167	2.12	8.82	.390	.047	17.40
6.4	20.00	29.7	1.43	.172	1.92	9.30	.380	.044	17.02
7.0	17.00	30.6	1.39	.196	1.95	9.33	.313	.041	16.21
				C. Lima Beans (Large Seeded Type)					
4.4	59.5	21.6	3.24	.302	2.72	5.07	.593	——	16.19
5.0	96.7	21.5	2.97	.354	2.38	6.43	.686	——	14.82
5.5	111.0	21.8	3.14	.397	2.42	6.60	.645	——	15.17
5.9	141.0	24.8	3.00	.415	1.98	6.60	.741	——	15.16
6.2	171.0	22.5	2.81	.457	1.84	8.60	.623	——	14.55
6.4	152.3	23.3	2.89	.466	2.11	7.15	.589	——	13.35
7.0	128.0	22.4	2.93	.478	2.07	7.54	.375	——	14.95

*Samples were taken at the time the crops were harvested.

There is a tendency, especially marked in garden peas, for nitrogen to accumulate in the plants grown at the lower pH values. However, when the growth factor is considered there is a gradual increase in the total amount removed from the soil due to the plant attaining a larger size under the less acid conditions. This large percentage of nitrogen present in the poorer plants eliminates nitrogen as one of the causal factors responsible for the poor growth conditions, and substantiates the observations made on the nitrogen content in the soil. Phosphorus is lowest in the poorer plants growing

under the most acid conditions on both a per cent dry weight and milligrams per plant basis, and shows a tendency to increase in the plant with decreased acidity in the soil. The total amount present in the plant increases with growth until a maximum amount is reached between pH 5.9 and 6.4, and then shows a noticeable drop under the neutral conditions of pH 7.0 This phenomenon has been previously observed at this Station (1) with lettuce, beets, and carrots and is in fair agreement with the amount of water soluble P_2O_5 found in the soil.

TABLE III—THE EFFECT OF THE SOIL REACTION ON PLANT COMPOSITION (EXPRESSED IN MILLIGRAMS PER PLANT)

Soil Reaction	Average Weight per Plant		N (Mgs)	P (Mgs)	K_2O (Mgs)	CaO (Mgs)	MgO (Mgs)	Fe (Mgs)	Total (Mgs)
	Green Gms.	Dry Gms.							
			A. Cabbage						
pH									
4.4	115	12.40	626	63	711	549	51	2.12	2046
5.0	189	20.40	937	106	947	1264	108	2.57	3480
5.5	315	23.87	920	129	1234	1791	126	4.06	4410
5.9	335	31.00	1294	181	1497	2334	178	5.56	5424
6.2	288	24.39	1018	144	1269	1761	121	3.31	4260
6.4	393	35.00	1222	204	1708	2305	142	4.56	5461
7.0	379	24.85	959	174	1388	1840	117	3.48	4810
			B. Garden Peas						
4.4	2.15	.745	23.0	1.3	25.0	51	6.4	0.75	160
5.0	6.07	1.84	37.8	2.2	63.4	176	11.5	1.11	382
5.5	15.80	4.50	70.6	8.7	108.5	398	23.2	2.24	840
5.9	18.20	5.26	81.5	10.6	117.2	459	18.9	2.31	943
6.2	19 10	5.17	71.9	9.0	112.9	470	20.8	2.42	900
6.4	20.00	5.95	84.9	10.2	114.0	552	22.6	2.62	1010
7.0	17.00	5.20	72.3	10.2	101.0	485	16.3	2.13	845
			C. Lima Beans (Large Seeded Type)						
4.4	59.5	12.84	416	38.6	350	651	76.0	—	2080
5.0	96.7	20.60	618	73.5	495	1334	143.0	—	3050
5.5	111.0	23.81	760	96.6	584	1598	156.3	—	3663
5.9	141.0	34.99	1048	145.3	692	2269	259.5	—	5301
6.2	171.0	38.41	1079	176.1	707	3300	239.2	—	5592
6.4	152.3	35.41	994	166.1	750	2543	208.8	—	4737
7.0	128.0	28.65	839	137.0	593	2149	107.5	—	4275

The amount of calcium as expected follows to some degree the amount added to the soil. However, in the majority of cases both the maximum amount and per cent found in the plant is reached between pH 5.5 and 6.2 and does not follow the increase in the water soluble material to pH 7.0 as noted in the soil. The largest single increases in the calcium content with one exception occur with the minimum application of the material between pH 4.4 and 5.0.

Magnesium, closely associated with calcium chemically, is absorbed to a greater extent at the lower reactions and is replaced by

calcium as the neutral point is approached. Potassium also shows some tendency to replace calcium at the lower reaction values and in turn to be replaced by calcium at higher reactions. A gradual decrease in the iron on a percentage basis was observed in the garden peas as the soil decreased in acidity.

It has been pointed out that above pH 5.9 no marked detriment to growth occurs. The slight variations noted can possibly be associated with the individual inherent capacities of the various crops to absorb the necessary nutrients under more acid soil conditions. The unavailability of phosphorus at the lower pH values has been suggested as a causal factor for poor growth; the lack of balance in the Ca–K ratio in the plant may also be advanced as another factor. The soil analyses and previous work at this Station (1) suggest that the large amount of soluble aluminum found in the soil between pH 4.4 and 5.0 probably also contributes to the lack of growth.

This preliminary report points out several possible approaches to a definite solution of the problem of soil acidity.

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Color of the Central Parenchyma of the Leaf Petioles as an Index of the Internal Root Color in Table Beets

By O. B. Combs, *University of Wisconsin, Madison, Wisc.*

MANY beet canners feel that in order to secure the most desirable canned product the beets used must have a comparatively uniform, dark red internal color as contrasted with the marked light zoning now found in most varieties. Plant breeders and other research workers have done considerable work in an effort to develop a variety or strain which would conform with this specification. In their selection work, however, these workers have been constantly confronted with the problem of determining the character of the internal regions of the beet without serious injury to the root and consequently endangering its subsequent usefulness in seed production.

Heretofore workers have been forced to obtain this information by either removing a slice from one side of the root, cutting a v-shaped piece from one side of the root, or removing a cylindrical plug from the root with the aid of a cork borer. These methods have been employed because no consistent direct relationship has been established between the degree of color in the internal regions of the root and any of the different top characters. It is obvious, therefore, that some such reliable relationship is highly desirable and would be very useful in the selection of the most desirable roots for seed production.

Observations made during the season of 1931 lead to the belief that a direct relationship exists between the internal root color and the amount or intensity of color in the central parenchyma of the leaf petioles. In order to obtain data which would either substantiate or discredit this belief, a number of varieties of table beets as well as a large number of strains of the Detroit Dark Red variety have been grown during the past 3 seasons. Samples were taken from each of these at intervals during the growing season and data recorded with reference to this relationship. The root was cut transversely with a sharp knife and the character of its internal color recorded as good, medium, or poor. The petioles were also cut transversely from 1 to 2 inches above their attachment to the root and the character of the color in their central parenchyma likewise recorded as good, medium, or poor. Sections of roots and petioles considered as good, medium, and poor respectively, were kept at hand in order that questionable samples could be compared with these as standards in case of doubt as to the classification to which the particular sample belonged.

During the course of the past three seasons (1931, 1932, and 1933), 1,901 were sectioned, classified, and the degrees of color of the internal regions of the root and that of the central parenchyma of their leaf petioles recorded. The collective data for these three seasons appear in Table I.

These data disclose the fact that of the 1,901 beets examined and classified, 75.43 per cent exhibited internal root color and petiole parenchyma color which were recorded as belonging to the same

color classification; 13.2 per cent were recorded as having better petiole parenchyma color than internal root color; and 10.31 per cent were recorded as having poorer petiole parenchyma color than internal root color.

TABLE I—Relationship Between Degree of Color in Internal Regions of Root and in Central Parenchyma of Leaf Petioles

Internal Root Coloring	Color in Central Parenchyma of Leaf Petioles					
	Good		Medium		Poor	
	Number	Per cent	Number	Per cent	Number	Per cent
Good	157	64.34	86	35.24	1	0.42
Medium	74	8.50	687	78.96	109	12.54
Poor	9	1.15	178	22.62	600	76.23

These results appear to substantiate the initial belief that there is a direct relationship between the degree of color in the internal regions of the beet root and that appearing in the central parenchyma of the leaf petioles. This direct relationship appears to be sufficiently consistent to justify its use in selection work with table beets.

The Effect of Soil Type, Soil Acidity and Organic Matter on the Growth of Beets, the Solubility of Aluminum and the Availability of Plant Nutrients

By JACKSON B. HESTER, *Virginia Truck Experiment Station, Norfolk, Va.*

IN a study of some of the factors that influence the growth of spinach, beets, and other vegetable crops under field conditions, certain relations between soil type, organic matter, pH values, and plant growth were found to exist. For example, spinach was found to grow well at lower pH values on some soils than on other soils. Further, in all cases soils containing high organic matter supported better growth at lower pH values than did the same soil types with low organic content. In order to obtain more definite information concerning the growth of vegetables on different soil types at varying pH values and organic matter content, the following research was attempted.

SOILS UNDER STUDY

Some of the salient characteristics of the soils used in this experiment may be found in Table I. The soils may be briefly described as follows: A Portsmouth loamy fine sand with high organic content and low pH value; a Bladen sandy loam, a gray mineral soil with low pH value and fairly low organic matter; a Norfolk very fine sand, a light yellow soil low in organic matter and plant nutrients. The Portsmouth and Bladen series represent comparatively young soils whereas the Norfolk represents a rather highly developed soil. All three of these soil types were found in the coastal plain section of Virginia and were taken from the virgin state.

TABLE I—SOME OF SOIL CHARACTERISTICS

Name of Soil Series	pH Virgin Soil	Pounds per Acre (7 inches- -2,000,000 lbs.)					
		Organic Matter	Nitrogen	Replaceable			CaO Holding Capacity (pH 7.0)
				CaO	MgO	K_2O	
Portsmouth..	4.1	154,200	6,380	830	360	270	15,240
Bladen......	4.4	36,000	1,180	375	260	182	5,720
Norfolk.....	5.0	18,600	960	286	236	134	2,680

EXPERIMENTAL PROCEDURE

The soils were brought to the greenhouse and placed in 2-gallon earthenware crocks of the coffee urn type. The bottom of the crocks are rounded to a small opening in the center which permits leaching of the soil. The pH values of the soils were varied with hydrated lime. The moisture content of the soil was kept at an optimum during the growth of the crop. Each one of the pots received 1.02

grams of nitrogen (ammophos, sodium nitrate, and ammonium sulfate), 0.93 grams of P_2O_5 (ammophos) and 0.93 grams of potash (muriate of potash). Five beet plants, 2 cm high, were set on June 13, fertilized on the 26th and July 7th and harvested on the 25th. The soils were leached on July 17 with rain water until a volume of about 1500 cc (the equivalent of nearly 2 inches of rain) was obtained. For ease of comparison all of the data are given in Table II.

TABLE II—THE EFFECT OF SOIL ACIDITY AND ORGANIC MATTER ON GROWTH OF BEETS, SOLUBILITY OF ALUMINUM, AND RELATIVE AVAILABILITY OF PLANT NUTRIENTS

Organic Matter Added (Tons per Acre)	Mean pH	Green Weight (Gms) Tops	Green Weight (Gms) Beets	Milligrams of Al_2O_3 Leached	Available Plant Nutrients (The Maximum Quantity Removed from Each Soil Type as 100) CaO	MgO	K_2O	N	P_2O_5
				Portsmouth					
	4.0	1	0	11.62	30	68	43	50	1
	4.8	94	12	0.22	60	61	43	69	61
	5.4	127	24	None	60	96	74	73	100
	5.8	139	26	None	65	84	79	77	92
	6.1	147	31	None	75	98	92	80	86
	6.2	154	33	None	100	100	100	100	89
				Bladen					
	4.2	1	0	0.86	43	51	21	34	9
	4.9	65	10	0.09	46	63	36	44	48
	5.1	100	16	None	56	67	54	67	56
	6.1	107	14	None	96	69	63	66	65
	6.8	86	9	None	100	46	60	72	67
				Organic Matter at Low pH 4.2					
10		17	2	None	53	49	35	34	27
20		108	17	None	35	90	73	74	70
40		125	22	None	44	95	100	93	90
				Organic Matter at Optimum pH 6.1					
10		104	23	None	67	71	72	76	73
20		122	23	None	63	92	81	85	96
40		119	17	None	96	100	82	100	100
				Norfolk					
	5.5	5	0	2.37	10	22	44	40	5
	5.7	64	4	None	18	21	47	32	27
	6.2	69	4	None	24	23	52	45	33
	6.6	58	3	None	39	21	69	56	31
	7.0	41	2	None	36	19	55	55	29
				Organic Matter at Low pH 5.5					
10		93	10	None	18	32	60	63	50
20		134	13	None	26	42	74	74	61
40		160	28	None	50	75	92	91	71
				Organic Matter at Optimum pH 6.2					
10		125	17	None	30	36	72	62	77
20		183	23	None	56	57	100	98	100
40		163	25	None	100	100	90	100	96

Soil Reaction and Plant Growth

The organic matter content and the quantity and composition of the mineral colloid control the absorbing power of a soil for lime. The soils used in this experiment varied in the lime holding capacity to pH 7.0 per acre (0–7 inch basis) from 2,680 to 15,240 pounds of calcium oxide. Since acid soils vary so widely in their power to absorb lime, it is not so much the question of how much lime has been added as it is whether or not the desired reaction is obtained. Instead of the quantity of lime that was added, the mean pH value developed is given. From this it is observed that the lowest pH value for good growth in the Portsmouth soil was 4.8, Bladen, 4.9, and Norfolk 5.7. The maximum yield for each soil, however, was at a reaction of around pH 6.2. The organic matter content of these soils suggests the importance of organic matter at low pH values.

Organic Matter and Plant Growth

Since the organic content of the Portsmouth soil was already high and supported growth at low pH values, no additional organic matter was added. In order to study the effect of organic matter on the growth of plants in the Bladen and the Norfolk soils, peat moss[1] was added to these soils at low and high pH values. The peat moss carried a very low pH (3.8) and was exceedingly low in available plant nutrients. When the organic matter was added to the soil at low pH a great increase in yield was obtained. The fact that the addition of the peat moss to the Bladen soil at the optimum did not increase the yield indicated that the advantage of the organic matter was not from the increased nutrients added but from the physical chemical action on the soil. Since the Norfolk soil was low in humus it responded to additions of organic matter at both low and high reactions. The yields were greater at high pH values in the Norfolk soil but a lesser quantity of organic matter was needed to give maximum yields. These facts indicate that the organic content of the soil must control certain factors such as the solubility of aluminum and the availability of plant nutrients.

Soluble Aluminum

The question of soluble aluminum in acid soils in relation to plant growth has received considerable attention in recent years. Varied opinions have been expressed regarding the role of soluble aluminum salts in toxicity to plant growth. It has been found that aluminum toxicity appears at one pH in one soil and at a different pH, higher or lower, in another soil. The pH at which aluminum ionizes and becomes soluble in a soil varies with the composition of the soil colloid. For example, aluminum did not appear in the water leached from the Portsmouth soil until the acid reaction of pH 4.8 was reached. On the other hand, aluminum was found in small quantities in the Bladen soil at pH 4.9 and in relatively large amounts at pH 5.5 in the Norfolk soil. However, when organic matter was added

[1]Obtained from Carona Peet Products Co., Duluth, Minn.

to the Bladen or to the Norfolk soil aluminum did not leach. This means that strongly negative soil materials (humates, silicates and phosphates) suppress the ionization and solubility of the ampholytes (aluminum, iron, etc.). This in turn makes it possible for crops to be grown at a lower pH value in some soils than in others. Further, the increasing quantities of humates must affect the available plant nutrients.

Available Plant Nutrients and Limiting Factors in Plant Growth

Since the earliest development of agriculture on a more or less scientific basis, soil scientists and agronomists have devoted a great deal of time to developing methods of determining the availability of plant nutrients. Liebig started out with the idea that the total chemical analysis of the soil would determine its producing power. Many thousands of chemical analyses have shown this method to be unsatisfactory. Milton Whitney stressed the value of water extracts as indicative of the available nutrients. This procedure has not proven altogether satisfactory. The Neubauer seedling method is proving very promising for determining the availability of certain nutrients but does not signify whether or not plants will grow in the undiluted soil. And again the Mitcherlich plant and pot culture method is giving very good results for certain nutrients.

The method used in determining the available nutrients or the limiting elements in plant growth for a specific crop in these soils may be classed as a combination of the principles of the above methods. For example, the beet plants were grown in the soil and just before they were harvested the soil was leached with an equivalent of nearly 2 inches of rain water. The plants and leaching water were both analyzed for certain plant nutrients. The results from these two analyses were combined to ascertain the available nutrients. The theory being that if the plants had not absorbed all of the available nutrients some would have been leached. Further, if some nutrient was the limiting element it would appear only in very small quantities in the leaching water. In order to simplify the presentation of the data the combined results are expressed in relative terms with the maximum quantity removed as 100.

Aside from aluminum toxicity phosphorus was the limiting element in the Portsmouth soil at pH 4.0. Its relative availability was 1 as compared with 100 at pH 5.4. The soil supported a yield of 127 grams of tops at pH 5.4 and only 1 gram at pH 4.0, which shows that there was a close ratio between growth and phosphorus availability at the two reactions. A deficiency of calcium, with a value of only 30 at pH 4.0, may also have been a contributing factor to slow growth, but apparently of lesser importance than phosphorus in this respect. Calcium, however, indirectly affected the availability of the other nutrients which in turn made it one of the limiting elements. For example, by correcting soil acidity aluminum was prevented from coming into solution which did not precipitate the phosphorus from

solution. It likewise affected the availability of the nutrients in affecting the activity of the soil micro-organisms and in affecting the vigor of the plant.

The data for the Bladen soil indicated that again, aside from aluminum toxicity, phosphorus was the limiting element at low pH values; an increase in pH from 4.2 to 4.9 resulted in a large increase in the availability of phosphorus and likewise in crop yield. When the organic matter was added the soluble phosphorus was prevented from being precipitated by the ampholytes. The addition of the equivalent of 10 tons of organic matter per acre at pH 4.2 increased the amount of available phosphorus from 9 to 27 per cent and the growth of tops from 1 to 17 grams. Further, an addition of 10 tons more of organic matter increased the amount of available phosphorus from 27 to 70 per cent and the yield from 17 to 108 grams. This soil had a rather high power for fixing potash. Soluble potash was noticeably low in all of the analyses for this soil without added organic matter.

The data for the Norfolk soil indicate that the presence of soluble aluminum and a deficiency of phosphorus were the limiting factors for growth at pH 5.5. When the reaction was raised the phosphorus values and also the yield of tops increased. However, satisfactory yields were not obtained without the addition of organic matter because the phosphorus values still remained relatively low. The fact that increases in yield at both the low and the optimum reactions, due to addition of organic matter, were accompanied by greater percentage increases of phosphorus than of the other elements indicates that phosphorus was a limiting element for growth. The calcium was noticeably low in this soil although the pH of the soil was higher than the other soils. At low pH values in the presence of organic matter the calcium possibly became the limiting element.

Since all pots received the same fertilizer treatment, the soil reaction and organic matter were the factors that influenced the availability of plant nutrients in these soils. Therefore, to obtain the maximum efficiency in supplying the plant nutrients of the soil for a specific crop the organic matter and pH must be held at an optimum point.

The results herein discussed are a more or less short review of the work. A complete discussion of the results will be published later in either "Soil Science" or in a bulletin from the Virginia Truck Experiment Station.

The Influence of Soil Type on Results From Paper-Mulch Trials With the Pepper and Eggplant

By K. C. WESTOVER and E. N. MCCUBBIN, *West Virginia University, Morgantown, W. Va.*

ABSTRACT

PLANTINGS of the pepper and the eggplant were made at Morgantown, West Virginia, on a DeKalb clay loam and at Lakin, West Virginia, on a Wheeling fine sandy loam in 1929, 1930, and 1931. The paper mulch as compared with ordinary clean cultivation gave conclusively better results with the pepper on the clay loam but there was little significance between the differences obtained with this crop on the sand soil, except for some of the early yields during the first two seasons. Much the same results were obtained with the eggplant, there being a stronger tendency for clean cultivation on the sand to give higher total yields of marketable fruits in 1930 and 1931.

In general, mulch paper on the clay soil significantly increased the number of pepper and eggplant fruits affected by rot. On the sand soil the mulch tended to cause more rotted peppers in the early season but fewer for the entire season. This treatment also tended to give a greater yield of rotted eggplant fruits in 1930 and 1931, and significantly increased the season's yield of sunscalded and cracked fruits the last season.

A critical study of the data on soil temperatures, moisture content, amounts of soluble nitrate nitrogen and acidity seems to indicate that the growth and yield differences obtained were primarily caused by the first two factors mentioned. These studies suggest that the use of mulch paper for these crops on light soils may be less profitable than on heavy soils.

The Use of Evaporation Records in Irrigation Experiments With Truck Crops

By E. Mortensen and L. R. Hawthorn, *Texas Experiment Station, Winter Haven, Tex.*

DIFFERENTIAL treatments in irrigation experiments have been based on various factors that are either dependent on uniform climate or on the irrigator's estimate except in the case of soil moisture percentages which require considerable time and expensive equipment. In a region of variable climate there was no simple dependable method in use to determine when to irrigate truck crops.

Previous experimental work has shown that amount of atmospheric evaporation as measured from a free water surface shows a positive correlation on a daily basis with the transpiration of the plant (2, 3). It does not correlate on an hourly basis or at short intervals (1, 2, 4). Other factors, such as age of the plant and season, appear to affect transpiration independently of evaporation but in general evaporation seems a fairly good index to the use of water by the plant.

Since evaporation records are taken as a part of the daily meteorological observations at the Winter Haven substation of the Texas Agricultural Experiment Station, it was decided to use accumulated evaporation from a free-water surface as a basis for the differential irrigation treatments in 1931. The observations are taken from a still-well in a circular tank 10 feet in diameter, using a micrometer gauge reading to .001 inch.

Definite accumulations of evaporation were arbitrarily decided upon as a basis for the first tests. Since weekly intervals seemed frequent enough and the average evaporation per week in the winter was about 0.75 inch, this was taken for the first treatment. Then accumulations were increased progressively by 0.5 inch for other treatments. A special book is kept with the accumulations for each treatment in a separate column. Entries are made daily and when a treatment is irrigated a line is drawn thru the column for that treatment and accumulation records begin at zero again. In case of light rainfall it is taken into account in the evaporation records but if the rainfall amounts to 0.5 inch or more it is arbitrarily called an irrigation and accumulations begin again from zero for all treatments.

In actual practice the accumulations rarely totaled to the exact amount required by the various treatments. The irrigations were made, however, as near to the accumulation decided upon as was practicable. In the winter season it was fairly easy to come close to the figure decided upon, for by watching the evaporation trend one could tell with fair certainty what the accumulation would be by the next day. Whenever the accumulation came within 0.05 inches of the figure set, an estimation was made and if the daily evaporation was around 0.1 or more the treatment was irrigated without further delay. In the summer because evaporation was usually much greater, knowing when to irrigate was not as easy. One day the accumulation

would be well below the figure set, yet a day later it might exceed that figure by as much as 0.1 or even 0.2 inches.

The first trial of this method was made in 1931–32 with Yellow Bermuda onions using three treatments of .75, 1.25, and 1.75 inches of accumulated evaporation. These treatments were run in triplicate with two guard rows between each plat. The furrow method of irrigation was used. Each plat consisted of three rows 109 feet long, with rows on ridges 16 inches apart, making a harvested area of .01 acre. The number of irrigations exclusive of rainfall from December 23, 1931, to April 21, 1932, inclusive, is shown in Table I. Rainfall during this period amounted to 3.09 inches, with only one rain counted as an effective irrigation. These data show that yields and grade were decreased by increased number of irrigations.

TABLE I—YIELDS OF ONIONS IRRIGATED AT DIFFERENT FREQUENCIES, 1931–32

Accumulated Evaporation (Inches)	Number of Irrigations	Average Acre Yield U. S. No. 1	
		(Bushels)	(Per cent)
.75	16	101	50.4
1.25	9	107	52.5
1.75	6	127	57.1

It is a common statement among onion growers that increasing the number of irrigations at bulbing time gives higher yields. To secure data on this point additional plats were provided whereby frequencies were increased on March 13 to 1.25 inches in two treatments which had previously been irrigated at 1.75 and 2.25 inches respectively. Another treatment of 2.25 inches throughout the season was added. Results are shown in Table II.

TABLE II—YIELDS OF ONIONS IRRIGATED AT DIFFERENT FREQUENCIES, 1932–33

Accumulated Evaporation (Inches)	Number of Irrigations	Average Acre Yield U. S. No. 1	
		(Bushels)	(Per cent)
.75	16	168	64.8
1.25	8	175	68.1
1.75	5	246	77.7
1.75 (later 1.25)	8	297	79.1
2.25	3	252	74.7
2.25 (later 1.25)	6	260	80.9

Rainfall during this period was 5.73 inches, of which three rains were counted as irrigations. Results from the first three treatments in 1932–33 conform in general to those of the previous year. The new treatments indicate that an increase in the rate of irrigation when the crop nears maturity is desirable. It appears then that the age of the crop must be taken into consideration, irrespective of evaporation.

Two crops of Bloomsdale spinach were grown in 1932–33 using four frequencies of irrigation, with .75, 1.25, 1.75, and 2.25 inches of accumulated evaporation, respectively, between irrigations. The first crop was planted October 31 and harvested January 24 and the second crop planted December 19 and harvested March 14. The results are shown in Table III.

TABLE III—YIELDS OF SPINACH IRRIGATED AT DIFFERENT FREQUENCIES, 1932–33

Accumulated Evaporation (Inches)	Number of Irrigations		Yield Untrimmed Plants (Pounds per Acre)	
	First Crop	Second Crop	First	Second
.75	5	6	6,870	4,210
1.25	3	3	6,560	4,430
1.75	2	0	8,250	4,610
2.25	1	0	8,470	4,470

During the growth of the first crop there was a total precipitation of 2.97 inches with one effective rain. The second crop received a total of 5.33 inches with three effective rains. With the second crop, some of the irrigations occurred just before a rain and caused a larger number of irrigations in the more frequent treatments. Weather during the growth of the second crop was unusually wet and in commercial fields irrigation was unnecessary. Differences in the treatments of the second crop are so small that they cannot be considered significant. Results from the first crop indicate that the more frequent irrigations tend to reduce yields, seeming to supply an unfavorable excess of water.

Missionary strawberries were grown in 1932–33 using 1.25, 1.75, and 2.25 inches of accumulated evaporation between irrigations. Plats consisted of three rows, 18 inches apart, 109 feet long with two guard rows between each plat. Between November 6, 1932, and April 15, 1933, 5.80 inches of rain fell of which three rains were considered effective as irrigations. A heavy freeze on February 8 and 9 caused a considerable decrease in the yield of the strawberries and probably affected the early results. In Table IV it will be noted that there were no significant differences between the three treatments.

TABLE IV—YIELDS OF STRAWBERRIES IRRIGATED AT DIFFERENT FREQUENCIES, 1932–33

Accumulated Evaporation (Inches)	Number of Irrigations	Total of 3 Plats	
		Stand	Yield (Ounces)
1.25	9	329	566
1.75	6	327	554
2.25	4	327	563

These treatments were continued throughout the summer of 1933 to observe the effect on plant formation and mortality. It became

necessary to change the 2.25 inch treatment on May 5 in order to save the plants and 0.75 inch was substituted. During the period from April 15 to November 1, 6.87 inches of rain fell of which four were counted as effective irrigations. Results in the number of runner plants formed are shown in Table V.

TABLE V—STRAWBERRY PLANT PRODUCTION AT DIFFERENT IRRIGATION FREQUENCIES—SUMMER OF 1933

Accumulated Evaporation (Inches)	Number of Irrigations	Mortality Mother Plants (Per cent)	Number and Grade of Runner Plants per Original Plant		
			Good	Poor	Total
0.75	48	3.68	17.4	9.5	26.9
1.25	32	3.99	15.7	9.3	25.0
1.75	20	14.07	12.4	8.0	20.4

Even though slightly greater yields were obtained with the more frequent irrigation, it is probably not worth while when the time and expense of the extra irrigations are considered. The interesting thing shown here is the apparently greater use of water by the strawberry plant in the summer than in the winter season. (Compare Table IV with Table V.) The 2.25 inch frequency was as good as any until hot weather set in when only a prompt change to more frequent irrigation saved the plants.

Soil moisture studies were not made so no data are available from these experiments on the correlation between soil moisture loss and evaporation from the water surface. Neither are figures available on the actual amount of water supplied the different plots; however, all plots were irrigated until thoroughly wet.

Results so far indicate that the use of accumulated evaporation as an index of frequency of irrigation is a simple, practical method for Southwest Texas growers. It furnishes a more dependable guide than those prevously used and should enable the grower to benefit by a more efficient irrigation program. The cost of the equipment is within the reach of the average farmer and the readings are simple.

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Response of Early Cabbage to Manures and Fertilizers[1]

By T. E. Odland, and F. K. Crandall, *R. I. State College, Kingston, R. I.*

An experiment was begun at this Station in 1916, designed to give more information on the manure and fertilizer requirements of certain of the market garden crops including early cabbage. This experiment with some modifications has been continued up to the present time.

Mack (3) in Pennsylvania studied the manure and fertilizer requirements of cabbage in a 4-year rotation of cabbage, early potatoes, tomatoes, and a cereal crop followed by grass and clover. He showed that a standard fertilizer which contained 60 pounds of nitrogen, 100 pounds of phosphoric acid and 80 pounds of potash produced earlier and larger crops than either 20 or 30 tons of manure. Ten tons of manure and a complete fertilizer gave higher yields than a green manure crop augmented with a complete fertilizer. The response to phosphorus was greater than to either nitrogen or potash. Comin and Bushnell (1) found that in Marietta, Ohio, nitrogen influenced the yields of cabbage more than either phosphorus or potash.

Crandall and Odland (2) in Rhode Island reported that early cabbage responded especially to nitrogen and that good crops could be grown with little or no manure.

Plan of Experiment

The chief purposes of the test was to determine to what extent fertilizer or fertilizer and green manure could be used to replace stable manure in growing certain market garden crops, one of which was early cabbage. Two rotations were planned having a 3-year cropping scheme. In one stable manure or peat was to be plowed in each spring while in the other green manure was to be substituted in whole or part for the stable manure. Two vegetable crops per year were to be grown in the stable manure rotation while in the other only one vegetable crop was grown each year with the remainder of the time given over to the growing of the green manure. Both stable and green manures were augmented with fertilizer except where the largest amount of stable manure was applied. No fertilizer was used on this plat until 1927. From this time on it has received the same amount of fertilizer as the standard plat.

Stable Manure:—As originally planned, the experiment provided for applications of 16 and 32 tons of horse stable manure in one rotation and 8 tons with green manure compared to green manure alone in the other. Changes in amounts and kind of manure have been made since 1925 but these have been of minor importance and need not be considered here. These changes probably affected the results

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little if any. A comparison of the 16- and 32-ton application of manure can be made for the years 1927–33 since the same amount of fertilizer has been used with these two manure applications for that period. The yields obtained with 32 tons of manure alone and of 16 tons with a complete fertilizer, may be compared for the earlier period 1916–1926, keeping in mind there are two varying factors. A comparison of yields obtained with various amounts of manure is presented in Table I.

TABLE I—YIELDS OF EARLY CABBAGE WITH VARYING AMOUNTS OF MANURE. BARRELS PER ACRE

Treatment	Years	Average Yield	Increase	Odds
32 T. stable manure	1916-25	273		
16 T. stable manure + 1300 lbs. 4-12-2	1916-25	338	65	1999:1
32 T. stable manure + 1500 lbs. 8-8-6	1927-33	526		
16 T. stable manure + 1500 lbs. 8-8-6	1927-33	534	8	3:1
Green manure + 1500 lbs. 5-12-4	1916-25	316		
Green manure + 1500 lbs. 5-12-4 + 8 T. manure	1916-25	343	27	46:1
Green manure + 1500 lbs. 8-8-6	1926-33	474		
Green manure + 1500 lbs. 8-6-6 + 8 T. manure	1926-33	519	45	2500:1

As may be seen from these figures, an annual application of 32 tons of manure alone produced an average yield of only 273 barrels per acre, 16 tons of manure plus 1300 pounds of a 4–12–2 fertilizer increased the average yield to 338 barrels per acre. The odds show this to be a significant increase in yield. A larger yield was produced with the lesser amount of manure and fertilizer at a considerably lower cost.

In the period 1927–33 when equal amounts of fertilizer were used with the 32 and 16 ton manure application there was no increase in yield obtained from the higher manure application.

In the other comparison in this table where green manure plus 8 tons of manure have been compared with green manure only, the average yield has been a little higher where the manure has been applied. The increase in yield has hardly been large enough to pay for this addition of manure.

Green Manures:—In the cropping plan of the green manure rotation, early cabbage followed a late celery crop of the previous year. This arrangement made it impossible to grow a crop to plow in immediately preceding the cabbage crop. However, two of the green manure crops were grown between the cabbage and the tomato crop of the following year. Oats, vetch, rape, rye, and two of the clovers were the crops used initially for plowing down. The clovers failed to make a satisfactory growth and were replaced by rye and timothy. Later, Japanese millet and ryegrass were also grown. Buckwheat and rye are the green manures being used at the present time. Samples of the rye crop grown, when fertilized, have shown

that as much as 15 tons per acre of green material can be grown by May 15th which will contain from 60 to 70 pounds of nitrogen. In Table II, a comparison is made between cabbage grown in the stable manure and green manure rotations.

TABLE II—YIELDS OF EARLY CABBAGE WITH GREEN MANURE AND STABLE MANURE. BARRELS PER ACRE

Treatment	Years	Average Yield	Increase	Odds
Green manure + 1500 lbs. 5–12–4......	1916–25	316		
16 T. stable manure + 1300 lbs. 4–12–2	1916–25	338	22	100:1
Green manure + 1500 lbs. 8–8–6.......	1926–33	474		
16 T. stable manure + 1500 lbs. 8–8–6..	1926–33	540	66	1798:1

In both periods, 1916–25 and 1926–33, the yield in the stable manure rotation has been a little higher than in the green manure rotation. In the first 10 year period the fertilizer used was not the same on the two rotations but for the last 8 year period it has been alike. In the stable manure rotation another vegetable crop is grown the same year while in the green manure rotation the remainder of the season is used for growing the green manure crop. Which rotation will be the more profitable will depend on the value of the land, cost of manure, and other factors. The experiment shows, however, that a satisfactory cabbage crop may be grown without the use of stable manure if green manure is substituted.

Peat:—The interest in peat as a substitute for manure was considered sufficient to warrant including it in this test. Its use was discontinued in 1930 as cabbage was the only crop which approached a normal yield with it. The peat used was a local product which was composted with lime for at least one year. The composted material was applied in sufficient quantity to supply an amount of organic matter equal to that in 16 tons of stable manure. The fertilizer used to augment the peat was varied somewhat from the standard in an attempt to obtain yields comparable to those where manure was used. Because of this difference in the fertilizers the yields with manure are not comparable to those with peat. The average yield per acre was 323 barrels for the years 1917 to 1925, and 460 from 1926 to 1930.

Lime:—No comparisons were made with varying amounts of lime. Frequent applications were made during the early years of the experiment, nearly 15 tons of limestone per acre had been used prior to 1925 when tests showed a pH of 7.0 or higher. No lime has been used since that time.

Fertilizers:—The standard or regular amounts and grades used with the stable and green manures have been mentioned previously in this paper. These were "home mixed" from materials purchased in the open market. The nitrogen was largely from nitrate of soda and sulfate of ammonia with a small amount from tankage. The phosphorus and potash were from acid phosphate and muriate of potash

respectively. Variations in the amount of nitrogen, phosphorus and potash content of the fertilizers were made in both rotations to determine their relative importance. The method adopted to obtain this information was to compare extra amounts of each with a standard or regular application. This scheme was followed for 10 years when reduced amounts of each were substituted and compared to the standard application. These reduced amounts were used where previously extra amounts had been applied, a plan which is open to criticism as any hold-over effect of the materials would modify the results obtained. The yields with the various fertilizers are shown in Table III.

TABLE III—YIELDS OF EARLY CABBAGE WITH VARYING AMOUNTS OF NITROGEN, PHOSPHORUS AND POTASH. BARRELS PER ACRE

Manure or Green Manure	Fertilizer		Years	Average Yield	Gain or Loss Over Standard	Odds
	Analysis	Amount per Acre				
		Green Manure				
Standard	5-12-4	1500	1916-25	316		
Extra N	10-12-4	1500	1916-25	350	34	96:1
Extra P	5-18-4	1500	1916-25	350	34	1523:1
Extra K	5-12-7	1500	1916-25	312*		
Standard	8-8-6	1500	1926-33	474		
Low N	4-8-6	1500	1926-33	408	-66	329:1
No P	8-0-6	1500	1926-33	482	8	4:1
No K	8-8-0	1500	1926-33	457*		
		Stable Manure				
Standard	4-12-2	1300	1916-25	338		
Extra N	6-12-2	1300	1916-25	405	67	9999:1
Extra P	4-18-2	1300	1916-25	338	0	
Extra K	4-12-4	1300	1916-25	337	-1	——
Standard	8-8-6	1500	1926-33	540		
Low N	4-8-6	1500	1926-33	459	-81	3332:1
No P	8-0-6	1500	1926-33	510	-30	24:1
No K	8-8-0	1500	1926-33	511	-29	37:1

* = This plat had a different green manure for this period so is not entirely comparable with others.

For the first 10 years of this experiment where extra amounts of nitrogen, phosphorus and potash were used the only increased yield obtained where stable manure was used was with extra nitrogen. In the other rotation the crop responded to phosphorus as much as to nitrogen and more consistently so, as indicated by the higher odds that it was a significant difference for this period. The last 8 years results substantiate the results of the first 10 with regard to a high nitrogen response for this crop. When phosphorus and potash were left out entirely in some mixtures for this latter period only small reductions in yield have resulted. No doubt this has been largely due to hold-over effect of these elements from the previous years when these

plats were used for the extra amounts of the same constituents. This fact should be kept in mind when considering these results.

Summary

Sixteen tons of manure supplemented by chemicals produced larger and more economical yields of early cabbage than did 32 tons of manure alone. An application of 8 tons of manure per acre in the green manure rotation increased the yields by 27 to 45 barrels per acre (about 10 per cent) over green manure and chemicals only.

In a green manure rotation such as used here, satisfactory crops of early cabbage can be grown with little or no manure. The use of 16 tons per acre of manure and chemicals produced about a 10 per cent increase in yield over the green manure and chemicals combination. Two crops of vegetables, cabbage, and beets, were grown in a season in the stable manure rotation while cabbage was the only cash crop when green manure was grown.

Nitrogen influenced the yields of early cabbage relatively more than did potash or phosphorus.

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Chemical Treatments for Shortening the Rest Period in Tubers of Jerusalem Artichoke

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NUMEROUS chemicals have been used in recent years to abbreviate the normal rest period in various plant structures, particularly in tubers and seeds. The present paper is intended to give a brief summary of results obtained with a number of chemical substances used while conducting experiments at Arlington Farm, Virginia, concerning the extent and nature of the rest period in tubers of the Jerusalem artichoke (*Helianthus tuberosus*). All of these substances have been used at various times by other workers, but with plant materials other than tubers of the Jerusalem artichoke.

Materials and Methods

In November-December of 1931, 1-ounce and 2-ounce tubers selected from four varieties (White Improved, Chicago, Waterer, Tait) grown at Arlington Farm, and dug before any freezing of the soil had occurred. The 2-ounce tubers were cut longitudinally into halves weighing approximately 1-ounce each, immediately before treatment. Twenty-five to thirty tubers or halves constituted a sample for each treatment. In December 1932, only 1-ounce whole tubers of the White Improved, and Chicago varieties were treated. Results of the 1931 work indicated a very similar response in both the whole and cut tubers except that when any treatment was toxic to the tubers, the toxicity was more evident with the cut than the whole tubers.

Three types of treatment were used: (a) The "Dip" method, in which the tubers were dipped into the chemical solution, removed immediately and planted, or in some cases placed in 2-quart screw top fruit jars for a given period of time before planting, to allow vapors from the chemicals to act on the tubers; (b) the "Vapor" method, in which tubers were placed in a metal container, the chemical placed in a shallow vessel on top of the sample and the can sealed for given periods of time after which the tubers were removed and planted; (c) the "Soak" method, in which tubers were submerged for given periods of time in a treating solution, then removed and either planted at once, or placed in covered 2-quart fruit jars for given periods of time before planting. All treatments were made at room temperature (approximately 70 degrees F).

After treatment, the tubers were planted in flats of damp peat moss. In the 1931–32 work all flats were kept in a cool greenhouse (45 to 55 degrees F) during the winter and spring months. In the 1932–33 investigations, in addition to the lots kept in the cool house, a duplicate lot for each treatment was kept in a warm greenhouse (65 to 75 degrees F). Near the end of the experimental periods in both seasons it was impossible to keep the day temperatures

from going somewhat higher than the desired temperature ranges. Controls consisted of 25 to 30 untreated cut or whole tubers planted at the time of making chemical treatments, and in the same manner as the treated lots.

At 15-day intervals from the time of treating, the tubers of each lot were removed from the peat, examined as to amount of sprout growth, root development and extent of rotting, and the sound tubers then carefully replanted. Such examinations were continued until all sound tubers had sprouted.

RESULTS

The results may be briefly summarized by the following classification which is based on the general behavior of the four varieties in 1931–32, and the two varieties in 1932–33. The dates "1932," and "1933" as used below refer respectively to the seasons of 1931–32 when plantings were made in a cool greenhouse, and to 1932–33 when plantings were made in both cool and warm greenhouses. "Days shortening" refers to the range in number of days the rest period was shortened compared with the corresponding varietal control treatments for the same season. The rest period of the controls in general was approximately 160 to 180 days.

A. Treatments producing some shortening of the rest period and having little or no deleterious effect on the tubers:—

1. Soaking in 20 per cent ethyl alcohol for 1 hour, followed by vapors 24 hours: 60 to 135 days shortening, 1932; 45 to 60 days shortening, 1933.
2. Soaking in 5 per cent Thiourea for 2 hours and planted at once: 45 to 105 days shortening, 1933.
3. Dipping in 2 per cent ethylene chlorhydrin solution, followed by vapors 24 hours: 30 to 120 days shortening, 1932; 90 to 120 days shortening, 1933.
4. Exposing to vapors of carbon disulfide 1 part in 35,000 for 24 hours: 15 to 150 days shortening, 1932.

B. Treatments producing some shortening of the rest period but with noticeable toxic effects on the tubers:—

1. Soaking in 20 per cent acetone 1 hour, followed by vapors 24 hours: 15 to 120 days shortening, 1932; 30 to 75 days shortening, 1933.
2. Dipping in 6 per cent ethylene chlorhydrin solution, followed by vapors 24 hours: 15 to 90 days shortening, 1932; 60 to 120 days shortening, 1933.
3. Exposing to ethyl bromide vapors, 1 part in 8,000 for 24 hours: 15 to 150 days shortening, 1932; 45 to 75 days shortening, 1933.
4. Exposing to carbon disulfide vapors, 1 part in 32,000 for 24 hours: 45 to 105 days shortening, 1933.
5. Exposing to chloroform vapors, 1 part in 20,000 for 24 hours: 45 days shortening, 1932; 45 to 60 days shortening, 1933.

C. Treatments definitely toxic and not shortening the rest period or so toxic that the extent of shortening could not be determined:—

1. Soaking in 50 per cent, 70 per cent, or 95 per cent ethyl alcohol 1 hour, followed by vapors for 24 hours, 1932.
2. Soaking in 3 per cent sodium thiocyanate for 2 hours and planted at once, 1933.
3. Soaking in 5 per cent sodium thiocyanate for 1 hour and planted at once, 1933.
4. Exposing to ether vapors 1 part in 2,000 for 3 hours, 6 hours, or 24 hours, 1933.
5. Exposing to ether vapors 1 part in 50, 1 part in 200, 1 part in 400, 1 part in 1,000 or 1 part in 2,000, for 24 hours, 1932.
6. Exposing to chloroform vapors 1 part in 50, 1 part in 400, 1 part in 1,000, 1 part in 2,000, or 1 part in 10,000, for 24 hours, 1932.
7. Exposing to chloroform vapors 1 part in 10,000 for 3 hours, 6 hours, or 24 hours, 1933.
8. Exposing to ethyl bromide vapors 1 part in 5,400 for 24 hours, 1932, 1933.
9. Exposing to carbon disulfide vapors 1 part in 17,500 for 24 hours, 1932.
10. Wrapping tubers in cotton batting saturated with 10 per cent hydrogen peroxide, removing the cotton after 7 days, 1932.

D. Treatments not toxic to tubers, but shortening the rest period very little or not at all:—

1. Soaking in 1 per cent, or 3 per cent sodium thiocyanate 1 hour, and planted at once, 1932.
2. Soaking in 1 per cent, or 2 per cent ammonium thiocyanate 1 hour, and planted at once, 1932.
3. Soaking in 5 per cent ethyl alcohol 1 hour, followed by vapors 24 hours, 1932, 1933.
4. Soaking in 5 per cent acetone 1 hour, followed by vapors 24 hours, 1932.
5. Soaking in 1 per cent, or 3 per cent Thiourea 1 hour, and planted at once, 1932.
6. Dipping in 0.5 molar, or 1.0 molar sodium nitrate, and planted at once, 1932.
7. Exposing to carbon tetrachloride vapors 1 part in 14,000 for 24 hours, 1932.
8. Exposing to ether vapors 1 part in 10,000 for 24 hours, 1932, 1933.
9. Exposing to ether vapors 1 part in 20,000 for 24 hours, 1932.
10. Exposing to ether vapors 1 part in 100,000 for 16 hours, 1932.
11. Exposing to chloroform vapors 1 part in 100,000 for 16 hours, 1932.
12. Exposing to ethylene chlorhydrin vapors, 1 cc 40-per cent solution in 1,300 cc. space, for 24 hours, 1932, 1933.
13. Exposing to ethyl iodide vapors 1 part in 48,500, or 1 part in 97,000 for 24 hours, 1932.

Studies made during the summer of 1933 indicate that the beginning of the rest period for tubers of Jerusalem artichoke still attached to the parent plant occurs about September first in the vicinity of Washington, D. C. Tubers treated in the present studies were therefore in their third or fourth month of rest, or physiologically speaking, in the "middle rest." In the light of the findings of Denny (1), and other investigators concerning the time of treating dormant plant organs with chemicals, it seems very probable that some of the chemical treatments found definitely toxic in the present study might have been less toxic if applied earlier, and that others found ineffective and non-toxic might have been more or less effective and possibly toxic if applied in later stages of rest than that worked with.

In Table I, are given the numbers of partially toxic treatments that caused various degrees of injury to whole tubers in the 1931–32 studies. The data cover all treatments (a total of 23) which were not 100 per cent toxic to all four varieties.

TABLE I—NUMBER OF PARTIALLY TOXIC TREATMENTS THAT CAUSED VARYING DEGREES OF INJURY TO DIFFERENT VARIETIES (A TOTAL OF 23 TREATMENTS USED)

Variety	Degree of Injury as Mortality in Per cent*				
	Very Slight 0–5	Slight 6–25	Medium 26–50	Severe 51–75	Very Severe 76–100
White Improved	11	8	4	0	2
Chicago	10	5	1	3	4
Waterer	2	9	7	1	4
Tait	12	4	4	1	2

*In all cases control treatments showed no mortality.

These data indicate that there are some varietal differences in susceptibility to injury by chemical treatments designed to break the rest period. Chicago and Waterer, particularly the latter, show tendencies toward greater injury than the varieties White Improved and Tait, as evidenced by the smaller number of treatments giving low percentages of mortality, and the larger number giving high percentages of mortality. It is hardly to be expected that any variety would invariably be more easily injured than others by *every* chemical treatment when the widely divergent character of the numerous chemicals used is considered. It is, however, reasonable to expect that for the *majority* of chemical substances used in breaking the rest period, certain varieties will be inherently more subject to injury. This appears to be true in the present case.

It seems of some significance that the varieties showing the most susceptibility to injury are also the ones tending to give the least shortening of the rest period with most treatments tried. This may indicate that injury is not necessarily a result of over stimulation but possibly due to some other cause. However, since only four varieties were used in this study, too much significance ought not be attached, at the present time, to this correlation between susceptibility

to injury and breaking of rest. Use of a large number of chemical treatments on a considerable number of varieties will be necessary before positive conclusions can be drawn.

While the rest period was shortened 15 to 150 days by the effective chemical treatments, subsequent growth was in all cases much slower than that induced when the rest period was broken by exposure of tubers to relatively low temperatures (32 degrees and 36 degrees F) for periods of 15 or more days (2), altho the tubers of both experiments were sprouted under the same greenhouse conditions.

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Some Factors Affecting the Absorption of Magnesium by the Potato Plant

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A DEFICIENCY of magnesium in the soil as indicated in reduced crop production, having reached noticeable proportions in the Atlantic Coastal Plain section, is receiving attention in field studies in Maine (3), Massachusetts (6), Connecticut (5), New York (1), Maryland (5), Virginia (1, 2), North Carolina (5), and South Carolina (4). In the Norfolk section potato, tomato and cabbage crop failures have been directly traceable by chemical analysis to a lack of sufficient available soil magnesium to meet the needs of the crop. The experiment reported in this paper was initiated for the purpose of determining effects of several sources of magnesium, of lime, and of large quantities of nitrogen on both the availability to the plant and the leachability from the soil of the magnesium ion.

Method of Procedure

Single 50-gram sprouted Irish Cobbler potato sets were planted March 1, under greenhouse conditions in previously fertilized soil, in completely glazed, self-draining 2-gallon jars. Each treatment (Table I), consisted of two similarly treated jars. Five leachings were made during a 7-week period by two alternating methods, using sufficient rain water to approximate accentuated spring rainfall conditions. The first method of leaching consisted in adding the equivalent of 2 inches of water to each pot and collecting and measuring the leachate; the second method of leaching consisted in adding just sufficient water to assure the leaching of the equivalent of 1 inch of rainfall. Additional uniform waterings were made when necessary. Each leaching was analyzed for its NO_3, NH_3, CaO, and MgO content. In Table I the appearance of the lower leaves of the plant, which can be used as an index of magnesium deficiency in potatoes is described briefly for each treatment. These observations, made 1 week before the plants were removed on May 1, can be compared with the MgO content of the material added, of the leachate, and of the aerial portion of the plant.

Discussion of Results

Under the high temperature conditions prevailing in the greenhouse and the small space allowed per plant it was impossible to develop the maximum potentialities of each treatment, which under field conditions had previously resulted in larger variations in plant size than are here indicated. Plants in treatments 1 to 7 on the lighter soil had a light green colored foliage and no very pronounced brown spotting or bronzing in the lower leaves, indicating that lack of nitrogen was probably as much responsible for poor growth as was lack of magnesium. Plants in treatments 8 to 15 on the acid soil had a very dark

TABLE I—THE EFFECT OF VARIOUS CONDITIONS ON THE ABSORPTION OF MAGNESIUM BY THE POTATO PLANT

Number	Treatment*	Condition of Lower Leaves	Plant Growth Grams per Plant		Magnesium (MgO)				
						Milligrams per Jar		In the Foliage	
			Green Weight	Dry Weight	Amount Added in (Lbs. per A.)	Added by Treatment	Removed by Leaching	Mgs. per Plant	Per cent Dry Wt.
A. On a soil low in organic matter (loss on ignition 1.25 per cent) and only slightly acid in nature (pH 5.75); approximate yield 45 barrels per acre									
1	Check	Yellowing	142	9.25	0	0	186	32	.341
2	Magnesium sulphate	Slight mottling	179	10.25	15	245	403	48	.471
3	Magnesium sulphate	Light green	224	21.60	30	490	628	98	.455
4	Sulphate of potash—magnesia	Light green, yellowing	182	8.50	15	246	377	40	.476
5	Hydrated dolomite	Dark green	173	9.90	30	492	652	75	.761
6	Additional nitrogen	Mottled—dark green	210	11.80	0	0	308	44	.374
7	Additional nitrogen plus $MgSO_4$	Dark green	231	14.78	30	492	681	113	.605
B. On a very acid soil (pH 4.3) with a high organic matter content (loss on ignition 4.96 per cent); approximate yield 30 barrels per acre									
8	Check	Bronzing	158	13.10	0	0	147	27	.206
9	Magnesium sulphate	Slight mottling	189	12.80	15	245	322	44	.342
10	Magnesium sulphate	Dark green	182	13.78	30	490	474	66	.478
11	Sulphate of potash—magnesia	Some mottling	190	14.00	15	246	232	47	.337
12	Hydrated calcium lime	Yellowing and bronzing	203	15.80	0	0	132	37	.237
13	Hydrated dolomite	Dark green	181	11.73	550	1,382	972	105	.896
14	Additional nitrogen	Browning and dying	209	16.05	0	0	205	41	.256
15	Additional nitrogen plus $MgSO_4$	Very dark green	212	14.75	30	492	664	69	.464

*Each jar received a 7–6–5 fertilizer applied at time of planting at an adjusted rate of 2000 pounds per acre. In treatments 6, 7, 14 and 15 additional nitrogen was applied to compensate for the amount leached. Lime was applied at the rate of 1500 pounds per acre to treatments 12 and 13.

green colored foliage and a heavy leaf growth but a definite mottling and bronzing in the lower leaves of some treatments, indicating that the primary cause of the trouble was not the lack of nitrogen but the lack of magnesium, which is substantiated by the fact that these plants contained 50 per cent more nitrogen on the average, and considerably less magnesium, than those in treatments 1 to 7.

A comparison of the amount of MgO added by treatment with the increased amount recovered in the leachate or found in the plant, indicates that either Epsom salts ($Mg\ SO_4 \cdot 7H_2O$) or hydrated Dolomitic lime is more easily leached and much more readily available for plant absorption than sulfate of potash-magnesia. On the acid soil, due to its higher organic matter content, less magnesium was lost by leaching, but the increased acidity of the soil did not seem to interfere markedly with the absorption of magnesium by the plant.

In treatments 6 and 7, and 14 and 15 the addition of sufficient nitrogen to the soil to replace the amount leached results in increases in the phosphorus and nitrogen contents in the plants and a darker color in the foliage. However, under neither soil condition (A or B) did the additional nitrogen completely offset the injury resulting when MgO was omitted from the treatment. On the lighter soil the additional amount of nitrogen was probably as beneficial to growth as the addition of magnesium but on the heavier soil additional nitrogen was ineffective unless accompanied by magnesium. This difference in the response of the two soils is due to the relative difference in their ability to prevent leaching of both nitrogen and magnesium.

In treatments 12 and 13 the effectiveness of liming with hydrated calcium and hydrated dolomitic lime can be compared. The use of calcium lime resulted only in increased alkalinity and higher calcium content of the soil but did not appreciably increase the available magnesium and, therefore, was of little value in making magnesium available to the plant. The analyses show that the use of a hydrated lime high in magnesium supplies a quickly available source of magnesium for the potato plant.

In soil B, in which nitrogen was not a limiting factor, indications of magnesium deficiency appeared in the lower leaves in every case where the MgO content of the plant was lower than 0.4 per cent. When the MgO content fell below 0.3 per cent the injury increased in severity and resulted first in mottling, then in a marked bronzing and finally in the drying up of the lower leaves. In soil A, which was low in organic matter, and consequently very easily leached, the percentage composition at which magnesium injury was noted cannot be as sharply defined under greenhouse conditions as it could in soil B in which nitrogen was not a limiting factor. Under field conditions, plants that contain over 0.4 per cent MgO, normally accumulated throughout the entire growing season, will not show symptoms of magnesium deficiency. A check treatment on another soil type indicated that under conditions of excessive rainfall during the early months of the potato growing season, magnesium probably would become a limiting factor on even the most fertile types of potato soil. It would seem highly advisable to include sufficient magnesium

in the fertilizer to adequately care for the maximum requirements of the crop merely as insurance against partial crop failure due to a deficiency caused by excessive leaching in an exceedingly rainy season.

Identification and Treatment in the Field

Magnesium deficiency is quite easily recognized in the field, but in the potato plant shows some different symptoms to those found and reported (7) for the tobacco plant. The general appearance of magnesium deficient plants may or may not indicate a lack of vigor, but in all cases the lower leaves have a mottled appearance and in later stages are covered with small necrotic spots and die prematurely. In every case an extreme brittleness of the lower leaves of the magnesium deficient plants is readily contrasted with the flexibility of the leaves of plants that are yellowing due to age.

In Table II, results are presented of a simple field test in which the chemical composition of 100 leaves from the upper and the lower portions of magnesium deficient plants is compared with that of a like quantity from the same portions of normally aging plants. The variations in the composition of the lower leaves of the plants from the two fields is extremely significant. Magnesium deficiency is characterized by a very low magnesium, rather low calcium, and quite high nitrogen content in the lower leaves. In normal aging, yellowing, or "going back" as it is called, the lower leaves are extremely high in both magnesium and calcium but quite low in nitrogen.

TABLE II—A Comparison of the Composition of Potato Leaves From Two Fields of Widely Divergent Yielding Capacities

Description	Expressed in	MgO	CaO	N
Field No. 1. (Low in soil magnesium) pH 4.9. Tuber yield 23 barrels per acre				
Poor lower leaves: brown and yellow spotted. Very brittle	Per cent dry wt.	.306	5.18	3.64
	milligrams per 100 leaves	80.8	1367	961
Upper leaves: green and rough Quite brittle	Per cent dry wt.	.440	7.32	4.72
	milligrams per 100 leaves	88.0	1464	944
Field No. 2. (Excellent state of fertility) pH 5.0. Tuber yield 52 barrels per acre				
Aging lower leaves: yellow and light green in color. Very flexible	Per cent dry wt.	1.100	13.25	2.65
	milligrams per 100 leaves	192.5	2319	464
Upper leaves: light green but smooth and quite flexible	Per cent dry wt.	0.685	7.95	4.83
	milligrams per 100 leaves	123.3	1431	869

The fact that potatoes require a rather acid soil condition for best results makes it necessary that all recommendations be based on a

definite knowledge of the soil reaction. On all soils with a reaction below pH 5.0 on which declining crop yields indicate some deficiency trouble, the addition several months before planting of a finely divided dolomitic lime at a rate sufficient to bring the soil up to a reaction of pH 5.2 or 5.3 should prove decidedly beneficial in the Atlantic Coastal Plain section. On soils in which the reaction is too high to allow any additions of MgO to be made through liming, fertilizer containing magnesium from a soluble source in a sufficient quantity to allow for an addition of from 20 to 30 pounds of MgO per acre in the fertilizer application made, should be used. If neither of these methods can be utilized, row application of 100 to 200 pounds of Epsom salts per acre immediately before planting will add sufficient MgO to care for the needs of an average crop. In any case the potential acidity in fertilizer can be advantageously neutralized by the use of a finely ground dolomitic limestone filler and thus eventually increase the available MgO in the soil.

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Influence of Different Fertilizer Treatments on Certain Characteristics of the Irish Potato

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FOR many years the opinion has existed among growers that certain fertilizer treatments affect the quality or general characteristics of fruits and vegetables. Much importance has been attached to the supposed low quality of fruits and vegetables receiving heavy application of nitrogen or receiving nitrogen from certain sources, and to the supposed high quality of crops receiving potassium. Differences have also been supposed to result from the use of potassium derived from sulphate and muriate of potash. Only recently have carefully controlled experimental methods been employed to determine the correctness of these oft-expressed opinions. The number of recent contributions in this field, however, attests to the interest of investigators in this subject. Much of the data now becoming available fails, in the main, to substantiate many of the beliefs which have been held relative to the effects of certain fertilizer treatments on quality (1, 2, 4, 5, 7, 8, 9, 11). In some instances it is quite apparent that other influences, such as rainfall, maturity, and storage conditions after harvest, greatly overshadow the differences due to fertilizer treatment (7, 10). In some instances, however, experimental data do show that certain fertilizer treatments affect fruits or vegetables in certain respects (2, 3, 10, 11).

An investigation was started at the Alabama Agricultural Experiment Station in 1926 to determine the influence of fertilizer treatments on the yield, grade, quality, and certain characteristics of several truck crops among which was the potato. In 1929 the outline of the potato experiment was modified and the location of the experiment was changed. For 7 years experiments have been conducted with the potato. Studies have been made of the influence on the tuber of the application of nitrogen derived from nitrate of soda, ammonium sulphate and cottonseed meal, of the application of potassium derived from muriate and sulphate of potash, of the omission singly of nitrogen, phosphorus, or potash from a complete fertilizer, and of the application of different rates of a complete fertilizer. Records have been made on yield, grade, keeping quality, sugar and starch content, total and soluble solids, conductivity, and respiration rates. Keeping quality has been determined by loss of weight in storage due to decay and to shrinkage, conductivity by a Wheatstone bridge with resistance box and Queen potentiometer, and respiration rate by Kimbrough's (6) adaptation of Gore's method. Carbohydrates have been determined by the Bertrand modification of the Munson and Walker method and total solids by drying to constant weight in a vacuum oven at 80 degrees C and 25 inches of mercury. The standard application of fertilizer, designated as N–P–K, consisted of 400 pounds of nitrate of soda, 800 pounds of superphosphate, and 150 pounds of

TABLE I—VIGOR, YIELD, PARTIAL COMPOSITION, AND SHRINKAGE OF POTATOES PRODUCED ON PLOTS RECEIVING DIFFERENT RATES OF FERTILIZER

Treatment*	Average Weight of top (Gms)	Yield per Acre (Bus.)	Loss of Weight in Storage—8 Months (Per cent)				Stored at 40°F—7 Months (Per cent)			
			Cellar	50°F	40°F	35°F	Total Solids	Starch	Total Sugars	Ohms
Check	308	41	28.8	15.9	10.4	14.0	20.7	16.6	2.4	49.5
½ (NPK)	647	105	25.8	11.4	9.1	8.7	19.4	15.3	2.3	45.1
NPK	856	137	25.6	10.5	8.4	7.8	18.6	14.1	2.1	42.5
2N2P2K	1,073	176	22.9	10.3	6.8	—	16.9	12.2	2.0	41.8

*N—400 pounds nitrate of soda; P—800 pounds superphosphate; K—150 pounds muriate of potash per acre.

TABLE II—YIELD, SHRINKAGE, AND PARTIAL COMPOSITION OF POTATOES PRODUCED ON PLOTS RECEIVING DIFFERENT RATE OF FERTILIZER

Treatment*	Yield per Acre (Bus.)		Loss of Weight in Storage at 40°F† (Per cent)					Total Solid 40°F Storage (Per cent)				Starch 40°F Storage (Per cent)			
	Incl. 1927–8	Average 1929–32	1927 3 Mo.	1928 8 Mo.	1929 7 Mo.	1930 8 Mo.	1931 8 Mo.	1927 Aug.	1928 Dec.	1929 Feb.	1932 Dec.	1927 Aug.	1928 Dec.	1929 Feb.	1932 Dec.
Check	6	63	10.3	11.3	8.5	17.4	10.4	23.1	22.2	20.5	20.7	17.2	15.2	12.9	16.6
½ (NPK)	—	134	—	—	7.9	14.6	9.1	—	—	—	19.4	—	—	—	15.3
NPK	28	168	6.6	8.5	7.6	14.5	8.4	22.0	20.2	20.1	18.6	16.4	12.7	12.8	14.1
2N2P2K	54	187	5.9	7.7	7.6	14.2	6.8	21.7	19.2	19.3	16.9	15.6	12.0	12.1	12.2
3N3P3K	56	—	7.3	9.8	—	—	—	21.6	19.1	—	—	14.5	11.9	—	—

*See footnote Table 1.
†Potatoes for analysis in 1927 were stored in cellar.

muriate of potash per acre. In 1927 and 1928, K represented only 100 pounds of muriate of potash.

Influence of Different Rates of Fertilizer

Throughout this experiment much greater and more consistent differences have been noted in yield, general characteristics, and behavior of tubers grown in plots receiving different rates of a complete fertilizer than of tubers grown in plots either receiving the fertilizer elements from different sources or receiving fertilizers from which has been omitted singly either nitrogen, phosphorus, or potassium. An examination of the data will show a marked response in the yield of potatoes to applications of a complete fertilizer up to 2,700 pounds per acre, an amount which represents a double rate of a standard application. This rate represents the practical limits of commercial application. For experimental purposes higher rates have been used especially to observe if such rates would upset the physiological balance of the potato plant or the tuber. Very small increases in potato yields have resulted from applications above 2,700 pounds per acre. In Table I it will be noted that for each of the three successive increases in the rate of fertilizer there was a material increase in the vigor of the plant and in the yield of tubers. There was in general a corresponding decrease in the percentage total solids, starches, and sugars at each higher rate, and a decrease in the percentage loss of weight during storage, the greatest difference developing generally between the no-treatment plot and the plot receiving the lowest rate of fertilizer. This trend was consistent for each period at which tubers were analyzed and for each storage temperature. It will be seen also in Table II how consistent this trend has been for the different years, each higher rate up to double applications producing potatoes generally having a lower storage loss and a lower percentage of solids and starches. For the triple rate, there was an increase in the percentage loss of weight in storage and a halt of the downward trend in the percentage of total solids and starches.

A further relationship between the rate of fertilizer application and the character and behavior of the potato is seen in Table IV. It should be noted that potatoes from the no-fertilizer plots had a considerably higher respiration rate than potatoes from plots receiving a standard rate of fertilizer, but that potatoes from plots receiving a quadruple rate had a higher respiration rate than potatoes from plots receiving a standard application. This is in line with the reversal of trends for shrinkage loss, total solids, and starch at the triple rate of application. There is a positive correlation in these data between respiration rate and loss of weight in storage.

The results indicate in general from a practical point of view that increases to a reasonable limit in the amount of fertilizer supplied result in increased yields and in smaller losses of weight at the various storage temperatures and give a potato which is entirely satisfactory in its starch content, sugar content, in its ratio of starch to sugar, and starch to moisture. On the other hand, the indications are

TABLE III—YIELD, SHRINKAGE, AND PARTIAL COMPOSITION OF POTATOES PRODUCED ON PLOTS RECEIVING DIFFERENT FERTILIZER TREATMENTS

Treatment*	Yield per Acre (Bus.)	Loss of Weight in Storage (Per cent)						Total Solids (Per cent)		Starch (Per cent)	
		1929 7 Mos.	1930 8 Mos.	1931—8 Months				1932		1932	
	1929–32	40°F	40°F	Cellar	50°F	40°F	35°F	Sept.	Dec.	Sept.	Dec.
1 PK	84	7.8	17.2	31.9	12.5	10.5	11.3	19.3	18.6	11.3	14.7
2 NP	139	6.4	14.3	28.0	12.1	7.5	6.0	19.2	21.1	14.9	15.7
3 NK	95	7.1	14.3	22.8	10.7	7.9	8.5	19.0	19.2	12.1	14.7
4 NPK (a)†	168	7.6	14.5	25.6	10.5	8.4	7.8	19.3	18.6	14.9	14.1
5 NPK (b)	159	9.5	13.2	27.0	11.8	8.0	7.3	18.8	18.3	13.3	13.4
6 NPK (c)	145	6.5	13.9	23.7	11.8	7.4	6.9	18.4	17.8	—	14.2
7 NPK (d)	167	6.4	14.8	23.8	10.6	7.4	6.5	19.6	18.7	14.5	13.6

*See footnote Table 1.

†Nitrogen derived in (a) from nitrate of soda; in (b) from ammonium sulphate; in (c) from cottonseed meal. Potassium in (a) derived from muriate of potash; in (d) from sulphate of potash.

that very heavy applications of fertilizers which produce no material increases in yield, may result in the production of tubers having a higher respiration rate, and keeping less satisfactorily in storage than tubers produced with a lower rate of fertilizer.

Effect of Different Sources of Material and of the Omission Singly of Nitrogen, Phosphorus, or Potassium from a Complete Fertilizer

In comparing the effects of different sources of nitrogen, it will be seen in Table III that a larger yield has been obtained from nitrate of soda than from sulphate of ammonia and that yields from cottonseed meal have been lower than the yields from ammonium sulphate. This has been consistent for each year. There has been no consistent difference in the loss of weight in storage of potatoes fertilized with nitrate of soda and sulphate of ammonia, although potatoes fertilized with cottonseed meal have consistently shown a somewhat smaller loss in storage than those fertilized with nitrate of soda. Very small differences in the percentage of total solids and starches have developed in potatoes receiving nitrogen from different sources, although potatoes receiving nitrate of soda have generally been slightly higher in total solids than potatoes receiving either ammonium sulphate or cottonseed meal. No consistent differences in yield, storage loss, total solids, or starches have been found between potatoes supplied potassium from muriate and those supplied potassium from sulphate.

TABLE IV—Respiration of Tubers From Plots Receiving Different Fertilizer Treatments

Treatment 1927	Milligrams of Carbon Dioxide per Kilogram per Hour						
	June 13 26°C	June 14 26°C	June 15 26°C	June 16 26.5°C	June 18 26°C	June 20 27°C	June 22 28.5°C
Check	28.6	23.5	19.4	17.3	14.3	13.6	14.0
PNK	20.8	17.5	13.5	12.6	10.2	10.2	10.7
4N4P4K	24.7	20.9	17.0	15.5	12.9	11.9	12.1
1929	June 1 29°C	June 2 29°C	June 3 29°C	June 5 29°C	June 7 29.5°C	June 10 28.5°C	June 13 27°C
2N2P2K (a)*	18.7	17.5	15.4	13.7	12.8	10.1	9.0
2N2P2K (b)	20.0	17.9	15.2	14.3	13.8	10.3	9.0

*Potassium derived in (a) from muriate and in (b) from sulphate of potash.

Comparison of yields of potatoes receiving nitrogen, phosphorus, and potassium with those receiving the various combinations containing only two of the elements, shows that the greatest response is attributable to nitrogen, with phosphorus response second, and potassium response third. The omission of nitrogen from a complete fertilizer results not only in a very large reduction in yield but in the production of potatoes having a high loss in storage. In total

solids and starches there seems to be no material difference between potatoes receiving no-nitrogen and those receiving a complete fertilizer. The omission of either phosphorus or potassium seems to affect very little the storage quality of potatoes or their percentage of total solids or starch.

In conclusion, it may be said that no very great differences in the characteristics of tubers have been found in potatoes receiving different fertilizer treatments but that certain small, yet consistent, differences have been found in potatoes receiving certain fertilizer treatments and those receiving other treatments. The most consistent relationship has been found to exist between potatoes receiving different rates of a complete fertilizer. The higher the rate of application of fertilizer the larger has been the yield, the better the storage quality, the lower the respiration rate, and the lower the percentage total solids, starches, and sugars until the double rates have been reached. Above this rate the trends are halted or reversed. Potatoes supplied a fertilizer sufficient for good production have kept well and have varied very little in composition regardless of the source from which each material has been derived.

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Factors Affecting Potato Seed Piece Decay

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IRREGULARITIES in the stand of plants in potato fields are often ignored. Too often growers are inclined to believe it is due to poor seed, whereas other factors are often responsible.

This paper deals with the value of suberized seed pieces for planting in warm soil, the condition of tubers in relation to decay and effects of soil temperature on seed-piece decay. It also presents briefly the relation to seed-piece decay of soil moisture, the use of dusts for cut seed and the methods of handling the cut seed pieces.

The healing of a cut seed piece is known as suberization. The first phase of the process of wound healing, according to Priestly and Woffenden (3) and Priestly and Johnson (2), is the deposit of suberin, a varnish like substance, around the walls of those cells at the cut surface. This layer, if perfectly formed, "blocks" the living cells within against the growth of molds and bacteria which would destroy them. After the suberin layer has formed the cells below the blocked surface give rise to a phellogen layer, or wound periderm, similar to the cork walls of the normal skin.

Priestly and Woffenden (3) found that when cut sets are exposed to a moist atmosphere the suberized layer is continuous, but when exposed to a dry atmosphere, especially in sunlight, the layer may be patchy. It is between these patches that the soil organism enters, destroying the set when planted.

Shapovalov and Edson (4) and Artschwager (1) found that the conditions prevailing in a moist chamber promoted the most perfect suberization. Artschwager (1) further shows that as the temperature increases up to 21 degrees C, the time required for the formation of suberin is shortened.

The condition of the tubers, according Shapovalov and Edson (4) affects cork formation. Badly shriveled potatoes, they state, do not heal over as well under any conditions as firm ones. Planting freshly cut sets from such tubers results in a complete decay of the seed pieces. Firm potatoes from good storage, although having produced sprouts, suberized properly when placed under the right conditions.

Procedure

The studies were made in greenhouses during the spring of 1932 and in a potato field in Spokane Valley during the summers of 1932 and 1933.

Certified seed stock of Earliest-of-All, Irish Cobbler, and Netted

[1]This subject was given to Mr. Pawson during his senior year in college as a Special Problem in Horticulture.

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Gem was employed. Seed pieces of 1¼ ounces were handled in three ways, (1) cut in advance of planting and stored one layer deep, cut surfaces exposed, at approximately 30 to 40 per cent relative humidity and at 60 to 70 degrees F, (2) cut in advance of planting and stored at about 85 per cent relative humidity and 60 to 70 degrees F, and (3) not cut until the day of planting. The low relative humidity (30 to 40 per cent) conditions compare favorably with air conditions at the time of planting late potatoes in the irrigated sections of Washington.

Lots of 20 seed pieces each were planted in duplicate. Soil temperatures were taken at the planting depth of 4 inches. As soon as the majority of the plants were above ground, all sets were dug, examined and the degree of rotting determined.

Relation of the condition of seed potatoes and of suberization to seed piece decay:—Experiments were conducted under conditions of both low and high soil temperatures to determine the effect upon seed piece decay of the sprouting and consequent shriveling of tubers and to compare freshly cut sets with those suberized before planting.

For the greenhouse test, firm, unsprouted Earliest-of-All potatoes were removed from storage two months prior to planting. One lot was placed in storage at 36 degrees F and was in a very firm condition when planted. The other duplicate lot was stored under room conditions and when planted was badly shriveled through sprouting and loss of moisture.

For the field tests Earliest-of-All and Netted Gem potatoes were used that were continuously stored in a good insulated common storage house until planted in early July. At that time the tubers were classified into three grades: "firm," "shriveled," and "badly shriveled."

Duplicate lots of 20 sets each were planted in a soil having a daily mean temperature of 75 degrees F in the greenhouse and 73 degrees F in the field. Seed pieces of each lot were planted immediately following cutting, while others were suberized in a humid atmosphere for 7 days.

The observations and data from these experiments indicate the following:

1. If potatoes are planted in warm soil immediately after cutting the percentage of germination is correlated with the firmness of the tubers.

2. For potatoes planted in warm soil proper suberization of the cut sets before planting is an aid in preventing seed piece decay, although when firm, unsprouted seed is used suberization is of no advantage.

Earliest-of-All potatoes planted freshly cut under field conditions (warm soils) gave the following percentage of germination: Tubers firm and sprouted, 90; shriveled, 72; badly shriveled, 67. On the other hand, all lots of potatoes suberized in humid air before planting germinated 100 per cent even when badly shriveled. Greenhouse tests gave essentially the same results.

To test effects of high and low soil temperatures on seed piece decay, two duplicate lots of potatoes were planted the first week in July, one in a soil having a mean temperature of 73 degrees F, and the

other of 58 degrees F. The plot at the lower temperature was planted in an insulated storage house and the other in the field.

Netted Gem and Earliest-of-All potatoes which had been kept in a common storage house until planted in July were quite badly sprouted. They were planted freshly cut and others were properly suberized. Irish Cobblers kept in refrigerated storage until 10 days of planting were treated in the same manner. For these tests quadruplicate lots of 20 each were made in the field plantings and triplicate lots were used at the lower temperature.

The results in every instance show a greater tendency toward seed piece decay at the higher temperature as was evidenced either by a lower percentage germination or a higher percentage of partly rotted sets. The data substantiating these conclusions are as follows:

Irish Cobblers (cold storage) planted freshly cut in soils at 73 degrees F, gave a 90 per cent germination with 32 per cent of the seed pieces slightly rotted as against a 100 per cent germination and 2 per cent slightly rotted tubers when planted in a soil at 58 degrees F. The same lot of tubers properly suberized and planted in the warm soil gave 100 per cent germination with 23 per cent of the tubers showing slight rotting whereas in the cool soil those suberized gave a 100 per cent germination with only two per cent of the tubers slightly rotted.

Sprouted Netted Gem potatoes (common storage) planted freshly cut in both a warm and a cool soil gave in the first instance a 56 per cent germination with the following percentage of tubers rotted, namely, slightly rotted, 24; badly rotted, 7; completely rotted, 44. In the second instance a 90 per cent stand was secured with the percentage of rotted tubers as follows, namely, slightly rotted, 8; badly rotted, 2; and completely rotted, 10. When this lot of potatoes was suberized a 100 per cent germination was secured in both the warm and cool soil, with 4 per cent slightly rotted tubers developing in the first case and 2 per cent in the second. Similar data were secured with shriveled Earliest-of-All planted both freshly cut and suberized in warm and cool soils.

These data also show that freshly cut shriveled tubers should give a high percentage of germination when planted in soils at 58 degrees F, whereas germination was unsatisfactory at soil temperatures of 73 degrees F. Suberization was found to be an aid in preventing decay of seed potatoes planted late in the season after the soil became warm but for planting under conditions of low soil temperature freshly cut and suberized sets were found to be of equal value.

Relation of seed piece decay of soil temperature and of methods of handling the cut seed:—Firm, unsprouted, Netted Gem potatoes were planted in duplicate in a greenhouse soil at 77 degrees F and in an outdoor soil which averaged 50 degrees F, from the time of planting until emergence of sprouts. Three sets of duplicates were planted, namely, (a) freshly cut seed, (b) seed cut and stored in a humid atmosphere for varying lengths of time, and (c) seed cut and stored in thin layers for varying periods of time under conditions of relatively low humidity.

The results showed that there was less tendency toward seed piece decay when sets were planted in cool soil than when planted in warm soil. This was brought out by the fact that sets suberized for three days in a dry atmosphere (30 to 40 per cent relative humidity) ruptured badly when handled, yet gave a perfect germination when planted in cool soil but only a 20 per cent stand for lots of the same tubers planted in a warm soil. With the firm, unsprouted tubers used in this experiment there was no significant difference between sets planted freshly cut and sets cut at various intervals before planting, provided the cut sets were suberized in a humid atmosphere. Cutting seed and exposing it to dry air conditions decreased the percentage of germination in direct proportions to the length of exposure.

Relation of excessive soil moisture to seed piece decay:—An attempt was made to determine whether or not soils wet and soggy for a period of time following planting were detrimental to a good stand.

Four lots of freshly cut and properly suberized potatoes were planted in a greenhouse with an average soil temperature of 57 degrees F but with a different water content for respective plots.

A perfect stand was obtained in all cases except that in which the soil remained "soggy wet" for the entire period. In that plot nearly all the sets were completely decayed. This indicates that poor stands sometimes resulting from early spring planting may be due, not to low soil temperatures, but at least in part to wet soil from which the air is excluded.

Siccatives in relation to seed piece decay:—Drying agents such as sulfur, lime or gypsum are generally recommended for the treating of cut potatoes. The literature, howover, does not show an unanimity of results as regards their value.

Different lots of seed pieces, freshly cut, of both firm and shriveled tubers, were thoroughly coated with each dust mentioned. One lot was planted at once and the other was treated after cutting but allowed to suberize in humid air for 7 days before planting. These lots were each planted in soils with an average mean temperature of 50 and 73 degrees F, respectively. Duplicate untreated checks were planted with each treatment.

The results showed very little seed piece decay in any of the lots when planted in cool soils regardless of the treatment. Under conditions of high soil temperature the use of these drying agents did not prevent seed piece decay. Instead in almost all cases the use of any of these materials increased decay. Sulfur was especially injurious. Lots treated with sulfur dust, without exception, showed either a low percentage germination or a higher percentage of partly rotted sets than did any of the other lots.

Summary

The following observations were made in regard to factors affecting seed piece decay:

1. At a soil temperature of 70 degrees F, or higher, there was relatively much seed piece decay. Other things being equal, a soil at

70 degrees F was less favorable to germination and a good stand than was a soil at 50 to 60 degrees F.

2. The percentage of germination of freshly cut sets when planted in soil above 70 degrees F was dependent upon the firmness of the tubers.

3. The decay of sets from sprouted tubers when planted in soil at 70 degrees F, or above, was minimized by suberizing the cut surface in humid air before planting.

4. Storing cut seed potatoes in a thin layer openly exposed to dry air (30 to 40 per cent relative humidity) was detrimental to germination, especially when the seed was planted at a time when the soil was above 70 degrees F.

5. Excessive moisture, such as to keep the soil "soggy-wet" for a long period of time produced much seed-piece decay.

6. Siccatives such as lime, sulfur or gypsum were detrimental when applied to cut seed, when potatoes were planted after the soil reached a temperature upwards to 70 degrees F, or above.

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Relation of Scalding Practice and Storage Temperature to Quality Retention in Frozen Pack Peas

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SOME of the advantages of scalding freshly prepared vegetables in boiling water, or exposing them to the action of live steam as a preliminary canning operation are common knowledge in the canning industry. The possible significance of these practices for the inactivation of enzymes associated with deterioration of the product was definitely suggested by Kertesz (1), who described the inhibition of respiration in peas during the interval between shelling and canning by treatment with boiling water.

When vegetables are sterilized at high temperatures, subsequent to a preliminary scalding applied as part of the canning operation, the survival of enzymes during the short period following the scalding is perhaps not significant. The enzymes are completely destoyed, in any event, at the subsequent processing temperatures.

However, for vegetables that are to be preserved by freezing, this survival may be of great moment and surpass in importance the obvious effects, which are sought in the scalding of vegetables subsequently processed by heat (2, 3). Low temperatures and ice formation do not completely inhibit enzymatic activity in plant tissues, although low temperatures do retard it (4). Recently, British investigators (5) reported that neither storage in vacuum at —20 degrees C (—4.0 degrees F), nor rapid freezing at —28 degrees C (—18.4 degrees F), —70 degrees C (—94.0 degrees F), or in liquid air at —192 degrees C (—313.6 degrees F) had any permanent inhibiting effect on autolytic enzymes in plant tissues. Observations at this laboratory have in the main confirmed these findings.

Unscalded peas stored at freezing temperatures may develop undesirable odors and flavors, which become particularly noticeable when the peas are cooked. The intensity of the odor may vary roughly with the period of scalding, when that treatment is inadequate, but is absent when the peas have been thoroughly scalded and properly stored.

The undesirable odors generally become distinctly noticeable in unscalded peas after 4 to 6 weeks storage at about 0 degrees F. Thereafter, these odors seem to increase in intensity and to be reflected finally in the flavor of the peas. This finding indicates that although unscalded or improperly scalded peas may appear to be in satisfactory condition at the time of freezing, the enzymatic activity eventually seems to produce a cumulative adverse effect on their quality.

The obvious economic significance of these facts and observations on the behavior of improperly scalded commercially frozen peas prompted some experiments designed to relate inhibition of enzymatic activity in peas to easily determined visual tests or to definite scalding procedures.

The extent of heat penetration produced by different periods of scalding of sized Alderman peas, (about number 3 cannery size), was compared with the catalase activity which was qualitatively demonstrated by action of hydrogen peroxide on the scalded peas. Samples from each scalding treatment were subsequently stored at —5, 15, and 20 degrees F for 5 months.

An index of heat penetration was calculated as the ratio of twice the width of the darker green translucent ring, characteristic of heated pea tissue, and observed when the pea was sectioned, to the entire diameter of the cotyledon, measured across its inner face.

Fig. 1 presents the relation of catalase activity qualitatively determined soon after scalding to index of heat penetration in Alderman peas, scalded for different periods of time at 210, 190, and 160 degrees F.

A study of the curves in Fig. 1 reveals a general correlation between catalase activity and heat penetration in scalded Alderman peas, as indicated by a color change in the pea tissues. It would seem that individual peas must show a color change affecting roughly at least 90 per cent of the cotyledon diameter before there is reasonable assurance of catalase inhibition, and by inference, general destruction of enzymes. The relation between the time factor for scalding at the different temperatures and the relative inhibition achieved by such treatment seems to correspond generally to the results reported by Kertesz (1) for preliminary scalding of Surprise peas intended for subsequent heat processing.

It should be noted for the experiments here reported, that the time and temperature factors were both significant in the inactivation of the enzymes and in the effects on the texture and appearance of the peas. For instance prolonging the scalding in water at 210 degrees beyond the 30-second period seemed to serve no useful purpose in destroying enzymes but did result in an undesirable softening of the peas and a slight fading of the brilliant green color characteristic of scalded Alderman peas. (Parrot green, Plate VI, or slightly darker, Ridgway color standards (6)).

Five months after the variously scalded peas were stored, samples were removed from the 20 degrees F storage together with raw peas, similarly frozen. All the samples were thawed at room temperature and subjected to organoleptic examination, to tests for catalase activity and to cooking trials.

Even before thawing was completed, the undesirable odor, similar to that of old hay and the unsavory flavor were noted in the unscalded material. Peas scalded for 30 seconds or longer in water at 210 degrees F were entirely satisfactory in both respects, both in the uncooked and in the cooked samples. The same was true for peas scalded in water at 190 degrees F for 50 seconds and at 160 degrees F for 105 seconds.

Catalase tests with hydrogen peroxide on this unscalded and scalded material after storage and thawing gave essentially a duplication of the results obtained when the peas were prepared for storage. Visual examination for color changes in the tissue caused by heat penetration

also gave similar results, and the absence or presence and relative intensity of the undesirable odor definitely showed a correlation with these indices.

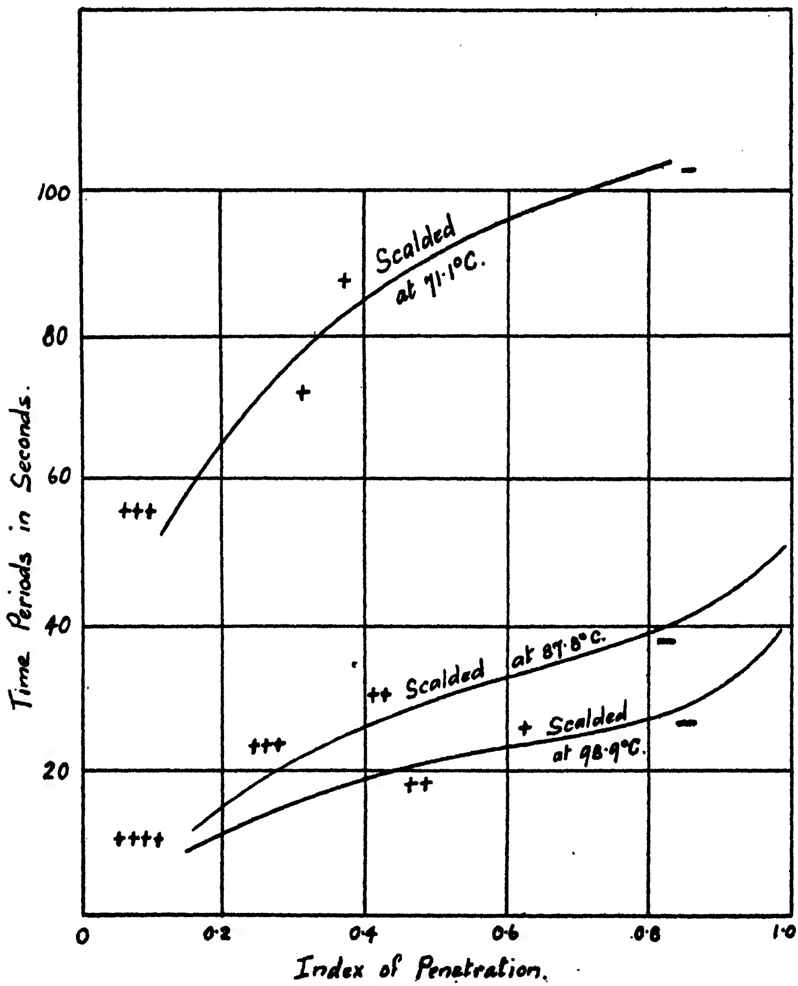

FIG. 1. Relationship of index of penetration and catalase activity in Alderman peas, scalded in water at different temperatures for different periods of time. Intensity of the catalase reaction is indicated by the number of plus marks.

In the course of the experiments with frozen peas and other vegetables, the importance of the rapid cooling of the scalded product to average tap water temperature of about 55 degrees F was emphasized. When heat processing follows immediately after the preliminary scalding, the rapidity of cooling the scalded vegetables may not be significant (8). However, continued heating of insufficiently cooled scalded

material, intended for freezing preservation, may result in undesirable changes in color and texture of the product. If considerable quantities of water are not available, it may be desirable to add ice or to otherwise refrigerate the water in order to cool the hot vegetables promptly.

Examination over a longer period of time, of collateral samples stored at —5 and 15 degrees F gave results similar to those described for peas held at 20 degrees F. However, on comparison, definite differences in the color of frozen peas were also observed, which seemed to be affected by storage temperature and not by the degree of scalding. For instance, at 20 degrees F only the unscalded peas showed any color difference when compared with all of the samples of scalded peas held at that temperature.

When observations on other samples of scalded Alderman peas, stored at 25 degrees F were included, the color of the different pea samples corresponded to the storage temperatures about as follows: —5 degrees F, parrot green, Plate VI, or slightly darker; 15 degrees F, lettuce green, Plate V; 20 degrees F, Javel green, Plate V and 25 degrees F, oil yellow, Plate V, the color trend, obviously being from the green to the yellow hues.

The retention of the original color of scalded peas for a long storage period was obviously achieved only at the —5 degrees F temperature. Material held at 15 degrees F, however, was by no means an undesirable product, and in other respects than color was equally as satisfactory as the peas stored at —5 degrees F. Even the color difference between the two lots was slight, and not particularly noticeable unless a direct comparison was made. However, the peas held at 20 and 25 degrees F had a distinctly inferior appearance, and of course, definite spoilage occurred soon in the material stored at the higher freezing temperature.

Very rapid freezing of Alderman peas in small containers immersed in liquid at temperatures as low as —85 degrees F (9), with subsequent storage at —5 to 10 degrees F did not more favorably influence color in the peas than when immediate storage of the material at —5 degrees F was employed.

These color changes, in which organic catalysts do not seem to be involved, since scalding for enzyme inactivation has no inhibitory effect, apparently are analogous to the deterioration changes in scalded peas noted by Kertesz (7). His suggestion that these changes may be caused through direct oxidation by atmospheric oxygen appears to be supported by our observations.

Organoleptic tests on uncooked as well as heated frozen peas after thawing, and microscopic examination of material, while it was still frozen as well as after it was thawed have not revealed significant quality or histological differences in properly scalded peas frozen in the temperature range —92 to 15 degrees F, with the exception of the color difference already noted. For the material frozen in the range —92 to —5 degrees F, storage in air at —5 to —10 degrees F was employed, while the peas frozen at 15 degrees F remained at that air temperature.

From these results, it would seem that very rapid freezing is not essential to quality retention in frozen pack peas, and that temperatures near 0 degrees F are satisfactory, providing reasonably rapid heat transfer is obtained in cooling the product and in finally freezing it.

Experiments with other frozen vegetables indicate that this is also true in a general way for asparagus, lima beans, corn, spinach, cauliflower, and beans, although minor modifications exist for some products. For instance, asparagus held at 15 degrees F was inferior to that frozen at —20 and —5 degrees F, and stored at —5 degrees F.

In conclusion, the experiments here reported emphasize the importance of adequate scalding and rapid cooling immediately thereafter for peas preserved by freezing, and indicate that temperatures about 0 degrees F are satisfactory for the commercial preservation of this vegetable. Similar experiments with some other vegetables not here reported in detail, indicate essentially the same facts for these also.

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Influence of Materials and Colors Upon Plant Temperatures Within Bags

By O. H. Pearson, *University of California, Davis, Calif.*

FOR some time it has been evident that success in securing seed from controlled pollinations is dependent to a large degree upon temperature. The material used for the isolation of flowers would conceivably have a great influence upon the amount of energy absorbed by the enclosed plant tissue and its resulting temperature.

In August, 1932, a series of tests were made of the temperature of tomato leaves enclosed in various materials being used for protective envelopes in plant breeding work. Bags of glassine, cellophane, white bond paper, manila, and muslin were constructed of about the same dimensions as an ordinary 1-pound square-bottom paper bag. A large cork stopper, perforated to hold a glass chemical thermometer was fastened into the bottom. The bag was inverted over a tomato branch. Four or five thicknesses of leaves covered the bulb of the thermometers. These bags were tied securely to laths and all given the same exposure to the sun. Air temperatures were taken by exposing the bulb of a thermometer directly to the rays of the sun. Although this is not the usual method for determining air temperatures, the daily maximums secured in this way were approximately the same as the official maximum temperatures recorded by the Davis branch station of the United States Weather Bureau. Temperatures thus secured could be compared with those registered by thermometers enclosed in otherwise empty bags. Leaf temperatures were taken with thermometers wrapped as the others, but not enclosed in bags. The wrappings were changed several times during the period of the test to avoid errors due to differences in installation. The temperatures recorded by standardized thermometers wrapped in this way may not represent the actual temperature of the leaves, but as the installations were alike, the differences secured would be comparable to the differences in actual temperature.

Temperatures were read each day at frequent intervals for the week, August 19 to 26, 1932. During the period the temperature of the air went to 108 degrees F on August 23 and 24, giving as severe a test as would commonly be expected. The changes in temperature within the bags for August 24, 1932, as compared with the air and unprotected leaf temperatures are shown in Fig. 1. The curves shown are typical in shape for the other days of the test, the only difference being in the maximum attained. The superiority of muslin for lowering the temperature of the leaf tissue is very evident, probably due to the increased transpiration possible as a result of removal of water vapor through the pores of the cloth. Manila and bond paper are nearly as good, with their maximum temperatures approximating that of the exposed leaf. Glassine and cellophane, however, were very much warmer, since they gave the enclosed tissue practically no shade and permit no loss of heat except by radiation.

The higher temperatures under glassine bags may partially explain the poorer set of beet seed under glassine than under kraft bags reported by Magruder (1932). The temperatures registered by the thermometers enclosed within empty bags were very much higher than that of the outside air. The muslin bag in this case was much the warmer.

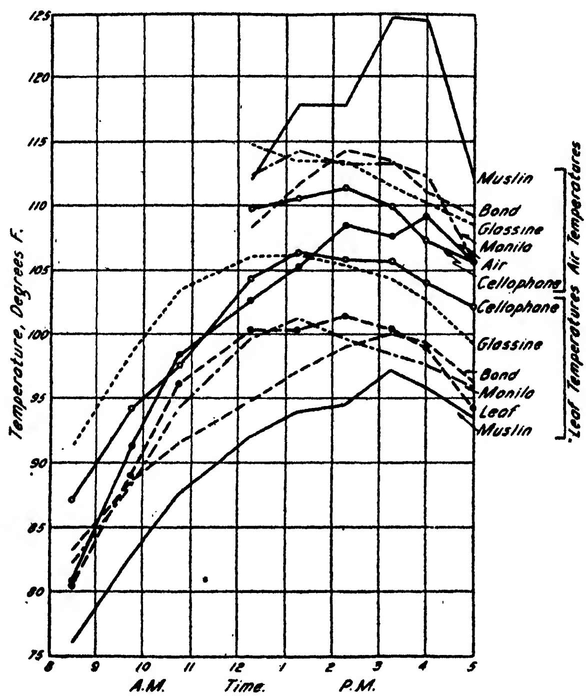

FIG. 1. Comparison of outside leaf and air temperatures with leaf and air temperatures inside bags of various materials on August 24, 1932.

Averages of the several readings taken at 3 to 4 p. m. during the week of trial are shown in Table I. The average temperatures at 3 p. m. for August 24, 25 and 26 of similar bags fully exposed to the sun but without plant tissue are also given. August 25 and 26 were relatively cool, so that the smaller number of readings represented in the average does not magnify but rather tends to reduce the differences between the two sets of readings. Fig. 1 also shows that the empty bags are much hotter.

The presence of colored cellophane on the market suggested that temperatures could be somewhat controlled by screening out light of certain wave lengths. The tests in 1932 (Table I) show that leaves enclosed in colored cellophanes were slightly cooler than the colorless, but those in bond paper washed with a 1–600 aqueous solution of Safranin O, Orange G, or Gentian Violet were warmer than the

TABLE I—AVERAGE TEMPERATURES OBSERVED AT 3 P.M. AND CONDITION OF PLANT TISSUE AFTER ENCLOSURE IN BAGS OF VARIOUS MATERIALS AND COLORS COMPARED WITH THAT OUTSIDE BAGS, AUGUST, 1932

Material	Leaf Temperature		Air Temperature in Tissue in Bag	
	Number of Readings	Average Temperature in Degrees F	Number of Readings	Average Temperature in Degrees F
Colorless cellophane	7	104.4	3	107.1
Manila	7	96.2	3	107.3
White Bond	7	96.6	3	110.3
White muslin	5	93.4	3	112.1
Glassine	4	101.2	3	107.3
Violet cellophane	7	102.8	3	112.1
Violet bond	7	102.2	3	110.7
Red cellophane	7	100.8	3	111.0
Red bond	7	97.2	—	—
Green cellophane	7	101.1	—	—
Green bond	7	95.9	—	—
Orange cellophane	7	103.3	3	109.0
Orange bond	7	99.0	3	106.9
Checks				
Leaf (Outside Bags)	5	95.0		
Air (Outside Bags)	7	102.2		

Condition of Tissue After Enclosure Within Bags of Various Materials for 9 Days

	Number of Branches Observed	Condition of Leaves	Condition of Flowers
Colorless cellophane	3	Severely burned	Burned and abscissed
Manila	4	Normal	Normal
White Bond	4	Normal	Normal
White muslin	3	Normal	Normal
Glassine	2	Severely burned	Burned and abscissed
Violet cellophane	3	Severely burned	Burned and abscissed
Violet bond	2	Normal	Normal
Red cellophane	3	Normal	Buds yellowed
Red bond	2	Normal	Normal
Green cellophane	4	Normal	Abscissed
Green bond	2	Normal	Some buds abscissed
Orange cellophane	4	Edges burned	Abscissed
Orange bond	2	Normal	Normal

colorless. The difference in behaviour was probably due to the large quantity of light which was reflected by the white bond paper, whereas a portion of the spectrum was absorbed by the dye in the colored bond bags, and was changed to heat. The higher temperatures of the colored bonds were due to this heat radiating into the interior of the bag. In the case of the cellophanes, very little light was reflected, most of it passing through to the leaf tissue. Colorless cellophane passed most of the light to the leaf, which was warmed; colored cellophanes passed only the unabsorbed and unreflected light, as well as part of the energy transformed into heat by their pigments. More

heat was lost by reflection of light and convection from the outer surface of the colored cellophanes than by radiation from the warmed leaves in the colorless so that the net result was that colored cellophanes were slightly cooler than colorless when sufficient leaf tissue was enclosed. Otherwise they were warmer than colorless because of absorbed energy.

In 1933 thermocouples were constructed of No. 28 iron-constantin and copper wire. They were inserted beneath an outer leaf of the group wrapped as above described around a thermometer bulb. The E M F was determined as against ice-water, and the temperature value taken from a calibration curve. Whenever the thermocouple was on the side of the wrapping exposed to the sun, the temperatures secured were the same as recorded on the thermometer, although the thermocouple was but one thickness of leaf removed from the direct rays of the sun, whereas the thermometer bulb was 4 or 5 thicknesses removed. Thermocouples would appear to offer a more rapid and accurate method of determination of leaf temperatures than the use of thermometers, and several attempts were made to use them in 1933. The results of these tests are shown in Table II. The installation consisted of holding two tomato leaflets together with "bobby-pins," the thermocouple between them. It was soon found that each installation had to be held in exactly the same plane as the others, and its true temperature could be determined but once a day, the time at which the sun's rays struck the upper leaf at right angles.

TABLE II—Averages of Thermocouple Readings Taken at 4 p.m. Underneath and Above Enclosed Leaves in Bags of Various Materials and Colors. Expressed in Degrees: July 19 to 27, 1933

Material	Number of Readings	Leaf Temperature	Air Temperature
Colorless Cellophane	6	102.5	106.0
Manila	12*	97.1	99.8
White Bond	6	93.9	98.0
White Muslin	6	96.6	100.2
White Muslin (Small)	10*	93.1	99.2
Glassine	6	102.4	105.2
Violet Bond	6	97.5	102.8
Violet Muslin	6	91.5	97.7
Red Cellophane	6	103.6	107.0
Red Bond	6	98.4	98.0
Red Muslin	5	93.2	99.1
Green Bond	4	97.6	105.1
Green Muslin	8*	94.7	100.1
Orange Cellophane	4	98.6	107.1
Orange Bond	4	95.6	99.8
Orange Muslin	4	94.1	99.5
Manila (Light)	4	98.0	102.8
Leaf	12*	97.6	——
Air	12*	100.3	——

*Duplicates, which checked within 1 degree, were run in these cases.

The air temperatures given in Table II were secured by thermocouples placed in bags containing leaves. They may be taken as ap-

proximating the temperature of the air directly above a stigmatic surface enclosed with a similar transpiring area. The temperature of this air might influence the germination of pollen on such a stigma. These air temperatures, however, are not comparable to those in Table I.

In 1933 muslin bags of the size used in these tests were dyed with aniline histological stains, the same as were used for the bond paper. The leaf temperatures within these bags, especially the violet, were slightly lower than those in white muslin (Table II), probably due to the greater shading effect.

The size of the enclosed space is an important factor because the proportion of pores to enclosed volume is much greater in the case of small as compared to large volumes. Two larger cages were constructed, 4 x 2 x 3 feet, one covered with white cheese-cloth, the other with similar cheese-cloth dyed purple. Air and leaf temperatures were taken for several days. The air temperatures within the purple cage were higher by 2.5 to 3 degrees F than in the white cage, and 6 degrees higher than un-enclosed air temperatures. Leaf temperatures were about 4 degrees F lower in the purple than in the white cage, about the same as the fully exposed leaf. Thus the leaf temperature in the large white cage was somewhat warmer than the check, while in the 1-pound size bag it was slightly cooler. Very small bags of heavy muslin, about 2 x 3 inches in size, were cooler than the larger bags in the main trial (Table II).

The loss of heat by convection from the surface of colored materials was shown by a simple experiment. Two closed cylinders of colored cellophane were constructed; one of these was enclosed within an outer sleeve of colorless cellophane. A half inch space separated the two layers. Both were exposed to the sun and a gentle breeze of 5 to 8 miles per hour. The temperature within each cylinder was raised by the absorption of light energy by the dye in the cellophane. The temperature within the cylinder with the sleeve was unaffected by the currents of air which cooled that contained in the other cylinder.

The condition of the leaves and flower buds after enclosure for 9 days in other bags of similar construction is shown in Table I. There were four to six bags in each series. In general, leaves showed injury in those bags whose temperatures were over 101 degrees F. Buds showed similar reactions. In the case of green bond paper, buds were injured although the temperature was not high. This may have been due to the small amount of light of the wave-lengths necessary for photosynthesis which penetrated the green bag.

This paper has described some simple tests on the temperature of plant tissue under bags. It has shown that the temperature of an empty bag of any material tested when fully exposed to the sun is much higher than when leaf tissue covers the thermometer bulb. It has also shown that there are distinct differences in temperatures of tissue enclosed in bags of various materials, depending on their shading effect, porosity, or energy transformation. Thus it would appear that a small bag, made of dark, highly porous material such as muslin, would keep the temperature down, while it could be appreciably

raised by using a transparent material such as cellophane or glassine, and that the ordinary manila or kraft bag apparently would keep the temperature of the enclosed leaf at about that of fully exposed leaves. However, other factors may be involved than those indicated in this paper, since our tests were made in the field, and the environment could not be controlled. The photo-chemical reactions within a plant are complex and its response to a given set of conditions is dependent upon many factors.

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The Effect of Temperature and Photoperiod on the Growth of Lettuce

By H. C. Thompson and J. E. Knott, *Cornell University, Ithaca, N. Y.*

THE failure to form solid heads, and the shooting of seed of lettuce plants, either without head formation or as the plant reaches maturity, makes desirable a knowledge of the factors concerned in head and seed-stalk formation. Various environmental factors may exert an influence. This paper covers some preliminary studies on the effects of temperature and of photoperiod on type of growth in head lettuce.

Seed of the White Boston variety was sown in flats in a medium temperature (60 to 70 degres F) greenhouse on December 3. The seedlings were transplanted to other flats, 2 by 2 inches, on December 22. The plants were shifted to 4-inch clay pots on January 25 and to 6-inch pots on February 17. On December 26, the plants were divided into three lots for preliminary temperature treatments. One lot was kept in the medium temperature house (60 to 70 degrees F), one lot was placed in the warm house (70 to 80 degrees F), and the third lot was placed in a cold house (40 to 50 degrees F). At the end of 15 days half of the plants from the cold house were returned to the medium temperature house. On January 25, one-third of the plants from each of the temperature treatments mentioned above were placed under three ranges of temperatures; cool (50 to 60 degrees F), medium (60 to 70 degrees F), and warm (70 to 80 degrees F). Half of the plants in each greenhouse were grown under the normal length of day and half under long-day conditions (15 hours). Each lot consisted of 15 plants and there were eight such lots in each of the three greenhouses.

The effects of the different temperature treatments on the subsequent growth in the cool, medium, and warm houses are discussed below.

Results

Warm temperature (70 to 80 degrees F):—In the high temperature house (70 to 80 degrees F) no heads were formed, either under the short- or the long-day, regardless of the previous treatment. An open rosette of leaves developed in each case. The seed-stalks began to appear on February 17 in the plants that had been continuously at the high temperature. Increasing the length of day did not appear to hasten the initiation of the seed-stalks. However, under a long photoperiod the seed-stalks elongated somewhat more rapidly than under a normal day. With long-day and high temperature, the order of appearance of the seed-stalks was: first, those plants that had been grown continuously at high temperature; second, those that had been subjected to a 40 to 50 degrees F temperature for 15 days; third, those plants that had been subjected to a 40 to 50 degrees F tempera-

ture for 30 days, and last those that had been held at 60 to 70 degrees F for 30 days. Under short-day the order was: first, those plants that had been grown continuously at high temperature; second, those that had been held 15 days at 40 to 50 degrees F; third, the plants of the 60 to 70 degrees F treatment, and last those that had been subjected to 40 to 50 degrees F for 30 days.

Medium temperature (60 to 70 degrees F):—All plants formed satisfactory heads in the 60 to 70 degrees F house, both under short- and long-day conditions, and there was no appreciable difference between the two lots. The first seed-stalks appeared a month later in the 60 to 70 degrees F house than in the 70 to 80 degrees F house. By March 20, a few of the plants that had been grown at 70 to 80 degrees F for 30 days had begun to elongate. Seed-stalk development under the various temperature treatments was in the same order as with a long photoperiod in the 70 to 80 degrees F house. However, in this case under a long-day the plants exposed for 15 days to a 40 to 50 degrees F temperature, developed 100 per cent of seed-stalks sooner than the 70 to 80 degrees F plants.

Cool temperature (50 to 60 degrees F):—Growth was very slow in the 50 to 60 degrees F house. Plants of all treatments made satisfactory heads except those that had been exposed to a 40 to 50 degrees F temperature for 30 days. Apparently these had been slowed down so much in growth that a 10 degree rise in temperature was not sufficient to let them catch up to the others. Under this temperature increasing the length of day materially increased the size of plant and head. By April 26, seed-stalks were appearing in the plants that had had a 70 to 80 degrees F temperature for the first 30 days. The remainder followed soon aftêr. The outside temperatures after April 15 were such that it was impossible to keep the greenhouse within the range of the 50 to 60 degrees F.

Summary

The 60 to 70 degrees F range in temperature was the most satisfactory for head formation. The previous treatment had no appreciable effect on heading. Tipburn on the mature heads was more severe at the 60 to 70 degrees F temperature range than at 50 to 60 degrees F. There was no tipburn in the warm house.

A temperature range of 70 to 80 degrees F under greenhouse conditions prohibited head formation, even with a short daylight period.

Heading was delayed about a month under a 50 to 60 degrees F temperature range compared to the 60 to 70 degrees F range. Seed-stalks appeared about a month later in the 60 to 70 degrees F house than in the 70 to 80 degrees F house.

The long photoperiod increased the size of heads at 50 to 60 degrees F only.

The 60 to 70 degrees F temperature treatment for 30 days had less effect on the initiation of seed-stalks than did the higher or lower temperatures, regardless of whether the plants were grown subsequently in the cool, medium, or warm house.

These results suggest that high temperatures during the early stages of growth of the lettuce in August may be largely responsible for the production of seed-stalks later in the fall. They also suggest that high temperature is an important factor involved in premature seeding of lettuce. Lettuce plants went to seed under high temperature, even under a relatively short day (10 to 12 hours).

The Cause of Flower Abscission in Plants of Varying Nitrogen and Carbohydrate Composition with Particular Reference to the Tomato

By F. S. Howlett, *Ohio Experiment Station, Wooster, Ohio*

Abstract

This material will be published elsewhere.

Pruning Greenhouse Tomatoes[1]

By A. P. DYE, *West Virginia University, Morgantown, W. Va.*

THIS experiment was conducted for a period of 4 years at the West Virginia University Greenhouses. The house used for this work is a modern one in good repair insuring good growing conditions such as light, temperatures, and ventilation. The soil was a rich loam, maintained by the annual addition of stable manure and commercial fertilizers.

"Stokes Strain of Bonny Best" tomato was used for this experiment. The seed was sown each year during the early part of December. The plants were set out in the permanent bed between the fifteenth and twentieth of February in rows 4 feet apart and 2 feet apart in the row.

Blocks of five plants each, constituted a treatment. Treatments were in quadruplicate and systematically distributed.

The treatments were as follows: Plot 1, check, the conventional one stem system most commonly used in this section; Plot 2, double stem trained to one upright support; Plot 3, same as Plot 1; Plot 4, double stem separated so that each stem had 12 inches of space for development.

The plants were kept suckered, and tied up as often as necessary. As each plant reached the top of its support, (6 ft.) it was topped. Hand pollination by the spoon method was practiced for the first few clusters of bloom on each stalk.

The weights of the fruits from each plant were recorded separately as they ripened throughout the season. The average total yield per plant in each plot was then computed. Results are shown in Table I.

TABLE I—EFFECT OF PRUNING THE TOMATO PLANT TO DIFFERENT SYSTEMS ON AVERAGE TOTAL YIELD OF FRUIT PER PLANT (POUNDS)

Year	Single Stem (Plot 1)	Double Stems Single Support (Plot 2)	Single Stem (Plot 3)	Double Stem Double Support (Plot 4)
1929.........	10.6	13.9	10.9	14.9
1930.........	14.4	20.5	16.1	22.2
1931.........	12.5	14.8	12.4	16.7
1932.........	12.8	16.3	12.9	18.2

Results were similar for all 4 years. The single stem plants produced the lightest yields. The double stem plots with both stems tied to the same upright support produced more fruit than the single stem plots but not as many as the double stem plots with stems tied to separate supports. The plots with the stems separated not only produced more fruits but they were much easier to care for than when tied to the same support. They were just as easily cared for as the single stem plants, and the net returns were much greater.

[1]Published with the approval of the director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 134.

Five Years' Field Study of Environmental Factors Affecting the Grade and Duration of Grade of Canning Factory Tomatoes

By F. C. Gaylord and J. H. MacGillivray, *Purdue University, Lafayette, Ind.*

Abstract

The complete data will be found in Purdue University Agricultural Experiment Station Bulletin No. 394.

During a 5-year period (1929–1933), tomato fruits were tagged as the blossom end became red at different canning factories in the state. These fruits were visited at definite intervals, usually every other day. All fruits on 10 to 20 plants in each plot were tagged. Records were obtained as to their grade according to U. S. tomato grades for cannery tomatoes. The information was collected as to number of days they were U. S. No. 2's, U. S. No. 1's, and U. S. No. 2's due to No. 1's rotting. These data have been summarized for plot or field, soil type, relative amount of foliage, weekly period, factory, and year.

There are variations in the percentage of tomatoes reaching the U. S. No. 1 stage (Table I). The low percentage U. S. No. 1's in 1931 may be due to a combination of hot, wet weather. A higher percentage of No. 1's is obtained the first half of the harvesting season. Medium or heavy foliage produces a higher percentage of U. S. No. 1's than light foliage. Sandy soil does not produce a high percentage of No. 1's in Indiana. Conditions responsible for producing a low percentage of U. S. No. 1's will also produce tomatoes which will be No. 1's for only a few days. Under average conditions, tomatoes will remain in U. S. No. 1 condition from 5 to 7 days and, in isolated cases, may be U. S. No. 1's for 30 days. The 1933 data are not included in this report.

TABLE I—A Summary of the Yearly Tagging Results Giving Grade and Duration of U. S. No. 1 Tomatoes

Location of Factory and Year	Matthews 1929	Franklin Trafalgar Brownstown 1930	Franklin Trafalgar Brownstown 1931	Matthews-Frankfort 1932
Number of plots	11	20	17	13
Number of fruits tagged	2928	5195	8181	1884
Percentage of fruits becoming U. S. No. 1's	76.4	90.2	29.2	72.4
Percentage of fruits becoming U. S. No. 2's only	19.5	8.4	42.1	19.3
Percentage becoming culls only	4.1	1.4	28.7	8.3
Average number of days U. S. No. 1's	3.8	8.3	3.2	7.3

A comparison between the actual grade obtainable from a field of tomatoes and the grade obtained by the grower cannot be definitely determined from these results, as the grower leaves his culls in the field and picking is not as accurate as in the tagging work. There are indications that a grower will more nearly reach the maximum obtainable percentage of No. 1's in a poor ripening season than in a good one.

Some Abnormalities in the Flower and Fruit of Lycopersicum Esculentum

By LEON HAVIS, *Ohio Experiment Station, Wooster, Ohio*

ABSTRACT

The original paper will be published elsewhere.

FRUITS of the commercial varieties of tomato varied greatly in size, shape, and number of flower parts. The primitive tomato characteristically had two carpels and there are a number of present day varieties where this occurs. Under cultivation the number of carpels has increased and often varies considerably in a given variety. The large number of supernumerary carpels present in some varieties, notably the Ponderosa, seemingly have no uniformity of arrangement and often possess thick, fleshy walls which result in fruits of prime importance to the horticulturist. Many other examples of supernumerary parts and also cases of adnation of parts were evident in this flower. Specimens were presented showing the arrangement of the carpels and their relation to the fruit as a whole. Specimens were also shown of fruits containing a small number of carpels and of others containing a large or supernumerary number.

In one fruit an anther and the style were undiverged and in another a filament and the ovulary were continuous.

In another example of unusual stamen development the stamen contained six pollen sacs instead of the usual four. In this case, there were two vascular bundles in the stamen instead of one. Pollen sacs sometimes occur in the petals. This situation is familiar to us in the "doubling" of flowers in which the stamens become petaloid and anthers, or abortive anthers are conspicuous on the petal as in the rose, carnation, canna, etc.

The remarkable plasticity of horticultural plants, as shown in the case of the tomato, is due to the potentiality which they possess of responding markedly to cultural and other environmental factors.

Factors Affecting the Production of Wrinkled Tomato Fruits[1]

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A FREQUENT source of loss to tomato growers lies in the production of irregular fruits from fasciated ovaries. This condition is especially common on the first clusters of both field and greenhouse plantings of most commercial varieties. The fact that the buds of at least the first cluster are usually initiated before the plants are placed in the field, or bed, indicates that conditions during the latter part of the plant production period may cause this fasciation. Crist (1) found that buds produced on hardened plants of Grand Rapids. Forcing developed into wrinkled fruits. The hardening in this case was accomplished by reducing the water supply. The writer (2) found that fasciation of the ovaries of John Baer occurred when the buds developed in relatively low temperatures, while buds which developed in relatively high temperatures were not fasciated. This paper deals briefly with some of the factors causing fasciation and with the stages at which it may be initiated.

SERIES I

On April 28, 1933, a group of 36-day-old, pot-grown tomato plants of the variety Nittany were divided into three lots, designated as A, B, and C. Within each group the plants were graded according to size and numbered from 1 to 32. Care was taken that identical numbers of each group were as nearly alike as possible. When treatments were begun the 12 largest plants in each group had cluster primordia large enough to be seen with the aid of a hand lens. (Magnification 7.5X).

On April 20 the plants had been subjected to an unplanned water shortage, which checked growth slightly, but by April 28 they seemed to have fully recovered.

Group A was placed in a room of the greenhouse where for 11 days after the beginning of the experiment the mean temperature was 76.6 degrees F. Group B was placed in a room where the mean temperature was 68.3 degrees F. Group C was kept in an unheated corridor where the temperature was approximately 10 degrees F lower than that maintained for group B.

After May 8 the outside temperature was so high that it was not possible to maintain temperature differences between the treatments. However, by this time all first cluster buds had been set.

By May 8, May 12, and May 16 the buds on groups A, B, and C, respectively, were large enough that the shape of the ovaries could readily be observed, and on those dates the first clusters of the various

[1]This work was presented in partial fulfillment of the thesis requirements for the degree of Doctor of Philosophy at Cornell University. It is here presented as Research Paper 336, Journal Series, University of Arkansas.

groups were harvested. Individual plant records were taken of the number and location of fasciated and smooth buds in each cluster.

None of the plants were in a hardened condition at the beginning of the treatments, but those in group C became slightly hardened by May 8; those in groups A and B were not noticeably hardened.

In each treatment the oldest one or two buds on each of the 12 largest plants contained fasciated ovaries. In general the younger ovaries in the same clusters were not fasciated.

In treatment B the buds which were initiated immediately after treatment was begun contained fasciated ovaries. Those on the smallest plants and the youngest of those on the medium-sized plants contained smooth ovaries.

In C all buds initiated after treatment began were fasciated.

It seems reasonable to assume that the fasciation observed in the oldest buds of all treatments was caused by the check in growth due to water shortage about April 20. Subsequent production of fasciated ovaries seems to have been directly related to low temperatures.

Series II

When the first bud-clusters of plants in treatment B of series I were sampled on May 12, the plants were in an unhardened condition and growing vigorously. On practically all of these plants the second cluster of buds had developed to such a point that they were easily seen without the aid of a lens. It was estimated that more than 50 per cent of the buds on these clusters had reached or passed the stage at which the stamens begin to develop.

On May 13, these plants were allowed to wilt slightly and thereafter the water supply was limited to the extent that growth was seriously checked, and the plants soon attained a moderately hardened condition. Temperatures remained relatively high.

By June 10 all the buds were large enough that the condition of the ovaries could be easily observed. All clusters were removed from the plants and the ovaries classified as to shape. Many of these had developed into fruits.

On the second clusters of the 30 plants involved a total of 170 buds had developed. Of these, 22 of the oldest had dropped off at the time of sampling. Of the remaining 148, 59 had smooth ovaries; 89 were fasciated. The smooth ovaries and fruits were uniformly the largest and oldest of the lot, and it seems reasonable to suppose that the dropped flowers, which were among the oldest, also had smooth ovaries. If this was the case, then 81 of the buds produced had smooth ovaries, and 89 had rugose ovaries.

These results indicate that the process of hardening by reducing the water supply resulted in the fasciation of those buds which had not yet reached the stage of stamen initiation.

It would be unsafe to conclude from such results that the time of stamen initiation is always the point at which fasciation occurs, or that it may not be initiated at a later stage of bud development. However, that stage is suggested as a probable critical point.

Meager though the data are, they indicate quite definitely that the ovaries of the variety Nittany may become rugose after a check in growth resulting from limited water supply.

Series III

This series was composed of two lots of plants grown in early and midsummer for observations on time and stage of plant growth at which bud initiation occurs.

Lot A was composed of 64 plants each of Earliana, Bonny Best, Globe, and Marglobe. Seed was sown June 13, 1933. Plants were spotted 3 inches apart in flats of rich loam soil on July 4. At that time the seedlings were "leggy" as the result of crowding in the seed bed and the first true leaves were about 1 inch long.

Lot B was composed of 192 plants of Earliana and 144 of Bonny Best. Seeds were sown July 4. Seedlings were spotted 2½ inches apart in flats of rich loam on July 13. At this time the first true leaves were barely visible. The plants were stocky and vigorous.

In lot A, buds of Earliana were first visible with the aid of a hand lens (7.5X) in from 30 to 36 days from the seeding date. Bonny Best required from 38 to 43 days and Globe and Marglobe from 43 to 48 days to produce visible buds. In lot B Earliana produced visible buds in about 14 days from seeding, while Bonny Best required about 23 days.

In lot A, at the time of bud initiation, plants of Earliana were from 2½ to 3 inches high; plants of Bonny Best were 5½ to 6½ inches, Marglobe 6½ to 7½ inches and Globe 2½ to 3½ inches high. In lot B Earliana plants were 1½ to 2 inches high and Bonny Best plants were from 5 to 6 inches high when the first buds were visible.

It is evident that neither age nor size can be used as an index to the time of initiation of the first cluster of buds, even within a given variety, as treatment and growing conditions may cause marked variations in both.

It was thought that perhaps the number of nodes below the first cluster might be more constant within each variety, and observations were made to determine the number of true leaves over ½ inch long which were present when the buds were first visible by use of a hand lens. In Earliana this was found to be 3 or 4, very consistently throughout both lots of plants. In Bonny Best the number was just as uniformly either 6 or 7 throughout both lots. Marglobe plants had from 6 to 8 over ½ inch long and Globe plants had from 5 to 7 such leaves at this stage of bud development.

Later observations on lots of 50 plants per variety showed that the total number of leaves below the first cluster of buds was quite consistently 8 or 9 in Earliana, 9 or 10 in Bonny Best, 9 to 11 in Globe, and 9 or 10 in Marglobe.

These results suggest that the grower may use the number of true leaves present on the plants of a given variety as an index to the critical period of bud initiation, so that he may govern his treatments during that time to avoid checking growth and causing fasciation of the ovaries of the first clusters.

They also suggest that earliness may be associated with the number of nodes laid down before bud differentiation occurs.

Series IV

Preliminary studies were made to determine the bud stage at which fasciation of the ovaries is first apparent. Two small fruited varieties were used. The first of these, designated as S, consistently produces smooth fruits, even when placed under conditions which cause Nittany to produce rugose fruits. The second, called R, produces wrinkled fruits under all the temperature conditions discussed in this paper and apparently regardless of the vegetative condition of the plants.

Buds of various ages were dissected under a binocular dissecting microscope. It was observed that sepals, petals, stamens, pericarp, and placental regions of the flower are differentiated in the order named. In both varieties the center of the primordium becomes slightly angular, the angles alternating with the stamens. This then elongates, the pericarpal regions at a slightly faster rate than the inner portions. Eventually the outer portions converge and, with some of the central tissue, elongate to form the style.

In the S variety the ovary primordia remain slightly angular for some time after stamen differentiation. This condition often lasts until the flower opens, at which time they become rounded in form.

In the R variety the ovary primordia are usually like those of the S variety at stamen initiation, but immediately thereafter the angular condition becomes extremely enhanced. Longitudinal grooves develop in the ovary opposite the stamens.

Studies of sectioned material indicate that these grooves are frequently, but not always, opposite the septa of the ovaries. The studies also indicated that in these two varieties a many loculed condition is associated with fasciation; that a few loculed condition is associated with smoothness of the ovaries. It should be remembered, however, that the many loculed condition is quite common in smooth fruits of commercial varieties.

Discussion

Hardening of tomato plants is of questionable value at any time. In raising plants for greenhouse or early field culture, they are ordinarily raised in such a manner that they may be transplanted without serious root disturbance. In such cases hardening to increase the rate of root regeneration is unnecessary. As the tomato cannot be made frost resistant by hardening, even plants for early setting would not be improved by the treatment.

In view of the above findings, then, it seems wise to avoid hardening of any type for tomato plants. The results indicate especially that low growing temperatures or water shortage at an early stage of bud growth may result in fasciation of the ovaries, a condition which carries over into the mature fruits.

The critical period, with respect to the first cluster produced, begins at about the time the cluster primordium can first be seen with the aid of a hand lens. It seems probable that this stage may be fairly uniform within a variety in relation to the number of leaves in evidence on the plants.

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A Study of Abnormalities in the Flower and Fruit of Capsicum Frutescens

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ABSTRACT

This complete paper will appear in the Journal of Agricultural Research.

PLANTS grown under high controlled (70 to 80 degrees F) and high uncontrolled (70 to 110 degrees F) temperatures produced a larger total number of both abnormal flowers and fruits than did like plants grown under a medium controlled (60 to 70 degrees F) temperature. Some plants produced no abnormalities regardless of the treatment received. Faulty nutrition and heredity are probably the two most important factors in the initiation of abnormalities in the flower and fruit of *Capsicum frutescens*.

Tomato Wrapping and Quality[1]

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THE wrapping of green-mature tomatoes in tissue paper for long distance shipment is an established practice in the commercial tomato growing sections of Mississippi. Growers believe that the paper not only enhances the attractiveness of the pack but that it also reduces injury in transit. The investigations of Sando (2) indicate that wrapping with paper interferes with the ripening processes and results in the development of poor flavor and low quality. The desirability of securing additional information on the subject led to the investigations reported herein.

The fruits were secured from plants of the Marglobe variety grown on the Horticultural Farm, State College, Mississippi. They were harvested in the green-mature stage of maturity, as indicated by the change from light-green to yellow-green at the blossom end and by the brown ring under the calyx. The samples were collected on the afternoons of June 10 and 20, 1932, and taken immediately to the laboratory where they were divided into two comparable lots identical in size, color, and condition of the abscission zone. One lot was wrapped in standard tomato wrapping paper; the other remained unwrapped. The fruits were then packed in 4-quart baskets and placed in a chamber approximating 50x30x40 inches. To prevent excessive shrinkage of the fruit a high relative humidity was maintained through the use of a shallow pan filled with water, and to prevent any oxygen deficiency the door of the chamber was opened for a short period at intervals of 12 hours. Temperatures in the chamber varied from 85 to 96 degrees F.

The fruits were removed from the chamber when the majority of them were soft ripe. Fruits of the June 10 harvest remained in the ripening chamber 7 days; those of the June 20 harvest remained 6 days. Selections from each lot were made for analyses. The softest and the firmest fruit in each lot were discarded.

Individual fruits were analyzed. They were sliced radially into 8 pieces and sufficient juice was hand pressed through a double layer of cheesecloth to determine the total acidity, pH, free reducing substances, and total solids.

Total acidity determinations consisted of diluting 10 cc of the juice with 25 cc of boiled distilled water and titrating against standard alkali using phenolphthalein as the indicator. Since the change in color was not sharp but gradual, the juice was titrated until a deep purple color was obtained.

The pH determinations were made electrometrically with a quinhydrone electrode, and the sugar determinations were made according to the Munson and Walker method of analysis. (A. O. A. C. 2d ed.) In both cases 10 cc of juice were utilized.

[1]The writer is indebted to W. B. Andrews, Soils Section, Mississippi State College, for criticism of the manuscript. Published with permission of the Director of the Mississippi Station.

The data in Table I show that titratable acidity, pH, free reducing substances, total solids, and free reducing substances/acid ratio of the juice of wrapped and unwrapped fruit were similar, since the differences obtained were within the limits of experimental error. No noticeable differences in flavor could be detected between the two lots. These results do not agree with those of Sando (2). His results show that fruit wrapped in a single layer of paper contained a greater percentage of titratable acidity and a lesser percentage of free reducing substances than fruit unwrapped. The wrapped fruit had a 3.01 sugar/acid ratio and the unwrapped fruit a 5.54 ratio. The wrapped fruit possessed noticeably inferior flavor, and Sando consequently concluded that the sugar/acid ratio was a good index to quality and that wrapping was unfavorable for the development of high quality.

TABLE I—INFLUENCE OF WRAPPING ON VARIOUS CONSTITUENTS OF THE JUICE OF MARGLOBE—1932

Treatment	Average Fresh Weight (Gms)	Total Acid as Citric (Per cent)	pH	Total Solids (Per cent)	Free Reducing Substances (Per cent)	Free Reducing Substances Acid Ratio
Wrapped*	214.8	1.17±.014	4.23±.010	5.75	1.22±.033	1.041
Unwrapped*	214.0	1.14±.023	4.28±.025	5.80	1.21±.016	1.096
Difference (wrapped minus unwrapped)		†0.03±.027	†−0.05±.027	†−0.05	†0.01±.035	†−0.055

*25 fruits in each lot.
†Differences are considered not significant.

Our results are not strictly comparable, however, since Sando (2) analyzed the whole fruit and the writer the free juice only. Rosa (1) has pointed out that the total acidity of the meaty portion and of the free juice is quite different. Apparently, the free juice is much higher in total acid content than the fleshy portion. This fact doubtless accounts for the lower sugar/acid ratios obtained in this investigation. The use of paper differing in permeability to gases may also account for a portion of the differences in the results of the two investigations. Sando (2) has pointed out that certain types of paper may retard gaseous exchange, particularly the movement of carbon dioxide and oxygen.

Since the wrapped and unwrapped fruit were similar in composition and flavor, and since the paper used is similar to that employed in the tomato shipping sections in Mississippi, growers need not expect this type of paper to develop poor flavor and low quality provided adequate ventilation is given in transit.

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Sex Ratios and Fruit Production Studies in Bush Pumpkins

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THE sex expression and sex ratios of various Cucurbitaceae have been investigated by Tapley (4), Tiedjens (5), Rosa (3), Erwin and Haber (2), Edmond (1), Whitaker (6), and others. As these workers have shown, the sex expression is typically monoecious or andromonoecious. The sex ratios and, in extreme cases, the sex expression may vary over a wide range under different environmental conditions. In a given environment, different species and varieties were found to have characteristic sex ratios, related to their particular growth and flowering habits.

In connection with a breeding project with the bush varieties of *Cucurbita pepo*, commonly called "summer squashes," certain data have been obtained on the following points: the sex ratios of three different varieties; the effect of environmental conditions on these ratios; and the effect on number of flowers produced, number of fruits set, and weight of fruits, of allowing fruits to develop for varying lengths of time. The sex expression of the varieties used in this study is typically monoecious.

Materials and Methods

The data presented herewith were obtained from two separate experiments. Experiment I involved the sex ratios and the variations in these ratios when plantings of three varieties—White Bush Scallop, Giant Summer Crookneck, and Zucchini—were made throughout the growing season of 1931. Ten hills of each variety were planted on May 9, June 8, July 6, August 3, and August 31, 1931. Commercial seed, known to be relatively uniform, was used throughout; and the hills were thinned to one plant each to allow for maximum growth. Records on flower production were taken daily. The staminate flowers were removed the day they opened, while the pistillate flowers were allowed to develop for a day or two, or until they reached marketable size. The plants in the August 31 planting flowered so late that no records were secured from them.

Experiment II involved the same three varieties as Experiment I. Thirty hills of each variety were planted on May 23, 1932, and were thinned to one plant each. The three varieties were each given six different treatments as regards the removal of fruits; five hills of each variety being treated similarly. The data for similarly treated five hills were averaged for each variety. In Treatment I, the staminate and pistillate flowers were picked daily; in Treatment II, three times a week; and in Treatment III, twice weekly. In Treatment IV and V, the staminate flowers were counted twice weekly; but the fruits were picked only once each week in Treatment IV, and every 2 weeks in Treatment V. In Treatment VI, no fruit was

picked until the end of the experiment. When the fruits were picked weekly or less often, only those that had set and developed normally were taken. The number of staminate flowers and the number and weight of the pistillate flowers or fruits were recorded.

Results

From a study of the number of staminate and pistillate flowers produced by each variety throughout the flowering seasons in the successive plantings of Experiment I, several facts are evident. (a) The variety White Bush Scallop greatly surpasses the other two varieties in number of flowers of both sexes; and Giant Summer Crookneck has considerably more flowers than Zucchini. (b) The staminate flowers were produced earlier than the pistillate. (c) The number of staminate flowers increased rapidly, reached a maximum, and then fell off as the plant neared the end of its normal flowering season. (e) The number of pistillate flowers produced increased less rapidly, showed no distinct peak, and continued to increase as long as records were taken. (f) The end-of-the-season decline in the production of staminate flowers was not observed with the pistillate flowers. (g) The average number of flowers per plant is greatest in the planting made on June 8, less in the earlier planting, and least in the two later plantings.

The sex ratios, or ratios of staminate to pistillate flowers, are given in Table I for the three varieties studied.

TABLE I——Sex Ratios in Three Varieties of *Cucurbita pepo* When No Fruits Were Allowed to Mature. Davis, California, 1931 and 1932

Variety	Flowering Period	Number of Flowers per Plant		Ratio S/P
		Staminate	Pistillate	
White Bush Scallop.........	5/30 to 8/15/31	430.1	83.8	5.14
White Bush Scallop.........	6/27 to 8/22/31	350.5	76.3	4.59
White Bush Scallop.........	7/18 to 9/5/31	237.4	46.4	5.12
White Bush Scallop.........	8/15 to 9/5/31	51.9	17.7	2.93
White Bush Scallop.........	6/15 to 8/14/32	296.0	91.2	3.25
Zucchini..................	5/30 to 8/15/31	139.8	70.4	1.99
Zucchini..................	6/20 to 8/22/31	120.2	24.4	4.93
Zucchini..................	7/18 to 9/5/31	64.1	15.5	3.28
Zucchini..................	8/15 to 9/5/31	23.8	2.4	9.92
Zucchini..................	6/15 to 8/14/32	209.2	34.9	6.00
Giant Summer Crookneck...	5/30 to 8/15/31	175.5	55.4	3.17
Giant Summer Crookneck...	6/27 to 8/22/31	211.6	39.4	5.37
Giant Summer Crookneck...	7/18 to 9/5/31	133.0	31.1	4.28
Giant Summer Crookneck...	8/15 to 9/5/31	36.9	9.5	3.88
Giant Summer Crooknech...	6/15 to 8/14/32	252.5	59.8	4.22

The data show no consistent variation in the average sex ratios of the different plantings in 1931 or of comparable plantings in 1932. The weekly ratios of a given planting, however, reached a high point near the early part of the season in both years and gradually decreased toward the end of the flower period. This relation would naturally result from the rates of production of the two types of flowers previously discussed.

Table II summarizes the data of Experiment II, showing the effect of allowing fruits to mature for varying periods on number of flowers produced, number of fruits set, and weight of individual fruits.

TABLE II—NUMBER AND WEIGHT OF FRUITS PRODUCED BY THREE VARIETIES OF *Cucurbita pepo* WHEN THE FRUITS WERE ALLOWED TO DEVELOP VARYING LENGTHS OF TIME. DAVIS, CALIFORNIA, 1932

Variety	Harvesting Interval	Average Number of Fruits per Plant	Average Weight of Fruits per Plant (Kilos)	Average Weight per Fruit (Gms)
White Bush Scallop	Daily	102.0	3.85	37.7
White Bush Scallop	Three times weekly	106.4	7.34	69.0
White Bush Scallop	Twice weekly	46.2	7.09	153.4
White Bush Scallop	Weekly	41.2	11.12	270.0
White Bush Scallop	Bi-weekly	20.8	13.55	651.5
White Bush Scallop	Termination of experiment	11.0	13.57	1,234.2
Giant Summer Crookneck	Daily	90.4	2.80	31.0
Giant Summer Crookneck	Three times weekly	52.4	2.90	55.3
Giant Summer Crookneck	Twice weekly	36.8	4.87	132.3
Giant Summer Crookneck	Weekly	30.0	6.87	229.0
Giant Summer Crookneck	Bi-weekly	17.0	8.78	516.5
Giant Summer Crookneck	Termination of experiment	4.4	7.56	1,672.3
Zucchini	Daily	45.6	1.87	41.1
Zucchini	Three times weekly	31.2	2.67	85.5
Zucchini	Twice weekly	25.6	7.49	292.7
Zucchini	Weekly	16.4	4.91	299.5
Zucchini	Bi-weekly	9.8	4.71	480.5
Zucchini	Termination of experiment	6.0	18.16	3,023.5

The results for the three varieties are in general quite similar. In each variety the number of fruits produced per plant decreased as the time they were allowed to develop was increased. At the same time, the total weight of fruits per plant and the average weight of single fruits increased rapidly. Because the results show certain differences in the behavior of the three varieties, they will be discussed separately.

As shown by the data for White Bush Scallop, the number of fruits per plant was the same when the fruits were harvested the day the flowers opened (treatment 1) or were allowed to develop for a day after opening (treatment 2). The average weight per fruit and in consequence, the total weight of fruits per plant was, nevertheless,

nearly twice as great in the latter case. When the fruits were harvested twice a week or were allowed to develop 2 or 3 days after anthesis (treatment 3), the number of fruits per plant was reduced by more than half. The total weight of fruit per plant, however, equalled that of treatment 2 and were nearly twice that of treatment 1, because the reduced number was compensated for by the increased weight of single fruits. When the fruits were allowed to develop for a week (treatment 4), the number per plant was only slightly reduced from that of treatment 3; but the weight per fruit and the total weight of fruits per plant increased approximately 50 per cent. If the fruits were harvested only every other week (treatment 5), the number per plant was reduced by half from that of weekly harvesting. The weight of single fruits was, however, more than twice as great as in the lot harvested weekly, so that the total weight of fruit per plant was slightly increased. When the fruits were not harvested until the end of the experiment (treatment 6), the number of fruits per plant was again reduced by nearly half; but the weight per fruit was increased inversely, with no change in total weight per plant.

The data show certain differences between White Bush Scallop, just discussed, and Giant Summer Crookneck. In the latter variety the number of fruits per plant decreased consistently as the harvesting interval was increased. This decrease was more than compensated for by a marked increase in weight of single fruits, with a consequent increase in total weight of fruits produced per plant.

The data for the variety Zucchini also show a decrease in number of fruits per plant with each increase in the time which the fruits were allowed for development. With this variety, the relation between the decrease in the number of fruits per plant and the weight of single fruits was less regular than in the other two varieties, perhaps because of the rate of growth for fruits of this variety or because the variation in plant size and fruiting habit was considerably greater than in the other two varieties. Additional data on rate of fruit growth may explain these irregularities.

Unfortunately, the vegetative vigor of the plants in the various lots was not measured in this study, being rather difficult to ascertain for this species. General observations, however, clearly showed that the size of the plant was reduced when fruits were allowed to develop to any extent. This reduction in plant size would be expected to cause a decrease in number of flowers produced. Although no records was kept of the pistillate flowers that did not set, all staminate flowers were counted. These data, together with the number of fruits set per plant and the ratio of staminate flowers produced to fruit set, appear in Table III.

In general, the number of staminate flowers decreased as the harvesting interval increased, although some exceptions occurred. This decrease was, however, not nearly so great as the decrease in number of fruits set per plant. The ratio of staminate flowers produced to fruits set, therefore shows a general increase as the fruits are allowed to develop for successively longer intervals. Further data to be collected may show some interesting results of the inhibitory effect

exerted by maturing fruit on vegetative growth and flower production in this species.

TABLE III—RATIO OF STAMINATE FLOWERS PRODUCED TO FRUITS SET IN THREE VARIETIES OF *Cucurbita pepo* WHEN THE FRUITS WERE ALLOWED TO DEVELOP FOR VARYING LENGTHS OF TIME. DAVIS, CALIFORNIA, 1932

Variety	Fruits Harvested	Number of Staminate Flowers per Plant	Number of Fruits Set per Plant	Ratio
White Bush Scallop	Daily	380.5	102.0	3.73
White Bush Scallop	Three times a week	294.7	106.4	2.77
White Bush Scallop	Twice weekly	357.1	46.2	7.73
White Bush Scallop	Weekly	284.3	41.2	6.90
White Bush Scallop	Bi-weekly	173.3	20.8	8.33
Giant Summer Crookneck	Daily	327.2	90.4	3.62
Giant Summer Crookneck	Three times a week	254.7	52.4	4.86
Giant Summer Crookneck	Twice weekly	251.7	36.8	6.84
Giant Summer Crookneck	Weekly	135.3	30.0	4.51
Giant Summer Crookneck	Bi-weekly	123.8	17.0	7.28
Zucchini	Daily	183.3	45.6	4.02
Zucchini	Three times a week	306.4	31.2	9.82
Zucchini	Twice weekly	171.3	25.6	6.69
Zucchini	Weekly	155.6	16.4	9.49
Zucchini	Bi-weekly	168.2	9.8	17.16

DISCUSSION

The sex ratio for three varieties of *Cucurbita pepo* used in Experiment I are lower than those usually given for other varieties of this species. Because the varieties used were the so-called "summer squashes," the fruits were removed at a very immature stage. The inhibitory effect of maturing fruit on the production of later pistillate flowers was therefore not present; and the ratios of staminate to pistillate flowers were lower than those reported for the field pumpkins and squashes where the fruits have been allowed to mature.

A significant reduction in the ratio of staminate to pistillate flowers has been observed when the daily exposure to light was decidedly reduced. In this study, the daily light exposure was probably never a limiting factor in flower production; and thus no change in the ratios was observed. The writer plans to obtain the sex ratios of these plants when grown under much reduced length of day—for example, in the greenhouse during the winter months.

Experiment II indicates that the physiology of fruit production is somewhat different in the three varieties. This difference is expressed in the variable effect of allowing fruit to develop for increasing periods, as shown by the number of flowers and the number and weight of fruits set in the three varieties. The varietal differences are probably explained by the vegetative vigor and rates of fruit de-

velopment in the three varieties. Future studies will provide data on these points.

The results of Experiment II show that the total weight of fruit produced per plant increased as the fruits were allowed to become more nearly mature. With these varieties, the fruit loses culinary value after an early stage in its development. To secure the greatest returns per plant, the grower must strike a balance between harvesting so early as to reduce total yield and allowing the fruit to become so mature that its market value is decreased.

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Pollen Germination and Development in the Watermelon

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THE watermelon, *Citrullus vulgaris,* when grown as a commercial crop, thrives best in regions of relatively high air temperatures and bright sunshine. The junior author (1), has demonstrated that fruit setting may be impaired by abnormally high temperatures; the rate is higher under comparatively cooler conditions. Data submitted in that publication were subjected to statistical analysis. As a result it appeared that temperature (rather than relative humidity) was a potent factor affecting the setting of fruit. The following study was planned to learn how temperature affects the phenomena that begin to operate immediately after pollination. The pollination technique previously described (1) was employed.

FIG. 1. Longitudinal section of watermelon style stained with resorcin blue, showing germination of pollen grains and progress of pollen tubes, 1 hour after pollination. X 35.

Aqueous resorcin blue (lacmoid blue) in a strength of 1:1,000 has been successfully used in this study for staining both the ovarian tissues and the pollen grains and tubes. This stain, specific for callose, was employed because it was thought that Citrullus pollen tubes might develop callose. Resorcin blue will stain callose a clear light blue; cellulose and the cell contents, various shades of slate blue to sooty; and the nuclear substance within pollen grains and recently germinated tubes, almost black. Fig. 1 shows the black pollen tubes, 1 hour after pollination, in the stylar tissues. After growing from 5 to 7 or more hours, however, pollen tubes are practically free from nuclear substance near their lower ends and are usually lightly stained with the clear blue characteristic of callose tissue.

In the following studies, the flowers were pollinated on July 25, 1933, at 9 a. m., 11 a. m., and 1 p. m. The ovaries were then killed and fixed in alcohol-acetic acid (4:1) at 2-hour intervals beginning 1 hour after each pollination, so as to provide pollinated flowers 1, 3, 5, and 7 hours old. Such lots were available for flowers pollinated at 9 and 11 o'clock in the morning; but only the lots for 1 and 5 hours after pollination were available for flowers pollinated at 1 p. m. Longitudinal sections of ovaries were cut at 20 and cross sections at 15 micra. The schedule followed in staining was to run the slides from paraffin to water in the customary manner and to leave them in resorcin blue overnight. The following morning, after a rinse in tap water, the slides were rapidly run through (a) 95 per cent alcohol, (b and c) two absolute alcohols, (d) half absolute, half xylol, and then (e) two changes of pure xylol, in the second of which they were allowed to remain about 30 minutes before being mounted in cedar oil mixed for immersion oil. Slides thus prepared indicated the progress of pollen tubes down the conducting tissue (shown stippled in Fig. 2), which comprises the entire stigmatic surface and then narrows down to a definite pattern running the entire length of the ovary. In the case of a four-loculed (exceptional) ovary, this pattern was that of a Greek cross with points oriented toward the four stigmatic lobes; it comprised the entire conducting tissue of darker staining cells, with numerous intercellular spaces between. The conducting tissue completely fills the four lobes for a considerable distance after passing the stigma. Upon reaching the first ovules, however, it does not fill the lobes at the ovular end, but gradually diminishes in extent until, at a point somewhat below the first ovules, it disappears altogether. A history of ovarian anatomy appears in Fig. 2, where a longitudinal section is compared with cross sections as seen at different points. All drawings were made with the camera lucida.

The pathway of pollen tubes from stigma to ovary is apparently confined to this conducting tissue as long as it lasts; thereafter, the tubes adhere to the cavity walls of the lobes on their journey to the ovules. Unfortunately, however, no tubes were observed fertilizing an ovule. Seven hours after pollination, the maximum observation in this investigation, is apparently an insufficient interval to effect fertilization. Whether the tubes first fertilize the ovules at the blossom end or the stem end is not known, although tubes had passed

beyond the position of the first ovules at the blossom end within 4 hours after germination.

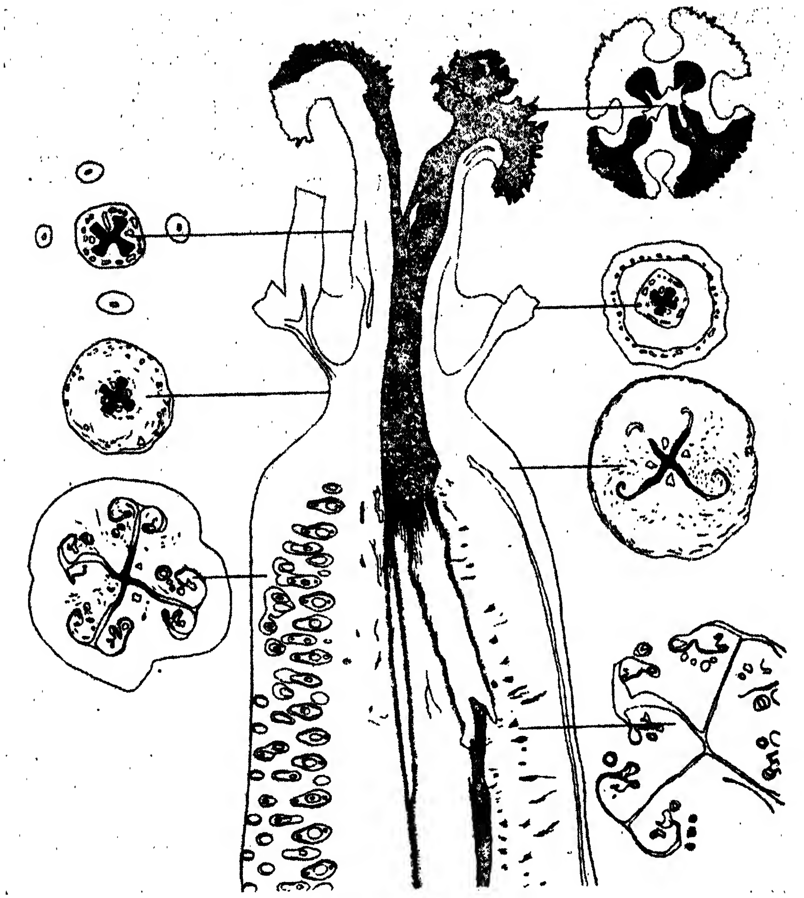

FIG. 2. Semidiagrammatic representation of watermelon pistil and tissues. Camera lucida drawings of a longitudinal section with cross sections at various positions indicated opposite; conducting tissue stippled.

The chief interest in the study, however, lies in the rate of pollen germination and of tube growth in relation to air temperature. Pollen-tube development was studied by projecting the microscope image of longitudinal sections, through the Zeiss microprojection apparatus, on a wall 115 centimeters from the microscope. In this way a magnification of 241 diameters was obtained. The length of pollen tubes for each ovary was then measured on the projected image in centimeters, and the maximum tube lengths for each section were recorded.

The results of these measurements are summarized in Table I,

which shows the time of pollination, the hours when ovules were fixed after pollination, the maximum length of pollen tubes for each fixation, and (in parenthesis) the number of millmeters' increase in tube length between fixations.

TABLE I—MAXIMUM POLLEN TUBE GROWTH

Time of Pollination	Temperature Under Cloth Bags (Degrees F.)	Hours after Pollination			
		1 (Mm)	3 (Mm)	5 (Mm)	7 (Mm)
9 a.m.	103	3.3	7.4 (4.1)	10.3 (3.0)	12.9 (2.5)
11 a.m.	112	2.5	6.5 (4.0)	9.1 (2.6)	11.1 (2.1)
1 p.m.	117	2.3	———	8.8 (6.5)	———

This tabular treatment shows a gradual and significant decrease in the length of pollen tubes for the last two pollination series. Likewise, in all three pollination series, the rate of tube growth diminishes as the tubes proceed down the conducting channels.

The distance from the stigmas at which the pollen tubes passed the first ovules, as recorded in four different cases, averaged 7.5 mm. Evidently, therefore, the first ovules at the blossom end were passed shortly after the third hour in those ovaries pollinated at 9 a. m., but somewhat later for the two subsequent pollination series.

The temperature under cloth bags was 103 degrees F at 9 a. m. and rose gradually to 117 degrees at 2 p. m.; thereafter, it gradually declined. The rate at which the pollen grains germinate after being applied to the stigma is apparently influenced by the temperature prevailing at the time of pollination. The maximum growth attained after 1 hour's exposure is significantly shorter as the temperature increases. On the other hand, the retardation of growth (indicated parenthetically in the table) as the tubes proceed down the conducting tissue is probably independent of external temperature. The 9 o'clock pollinations had reached their 7-hour growth at 4 p. m.; the 11 o'clock pollinations at 6 p. m.; yet both had approximately the same rate of retardation regardless of the accelerated growth to be expected from a declining temperature after 2 p. m.

A preliminary series of pollinations had been made on July 17. Although the technic of fixation was not so satisfactory and the hourly fixing intervals were not the same, the data on rate of tube growth showed essentially the same type of growth curve as observed on July 25.

It is not known to what extent the age of pollen may explain the retarding of pollen-tube growth down the clearly marked conducting channels. Sisa (2) notes that pollen grains of several Cucurbita species germinate more readily the day preceding anthesis and less readily after noontime on the day of anthesis. Whether or not this fact is connected with the growth retardation previously discussed is unknown.

In conclusion, the enhanced percentage of fruit set on cooler days obviously depends somewhat on the increased rate of pollen tube growth during the earlier hours of the day, when relatively low temperatures prevail.

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Carrot Breeding Experiments

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THERE are very few references in the literature to breeding work with carrots. Such improvement as has been made in varieties has been done largely by selection and isolation. In the few studies that have been reported (3, 4, and 5) the presence or absence of self-sterility appears to have been the character that has received the most attention. There is practically no information available as to breeding methods, effect of continued inbreeding and the method of inheritance of such characteristics as shape and color. With the increase in carrot production that has taken place in the last few years there has come a definite need for this information.

Since carrot flowers are small and difficult to emasculate and a single flower produces only two seeds, hand-pollination is very laborious. It is the purpose of this paper, therefore, to describe a technique developed to secure self- and cross-pollination and to report results of inbreeding.

BREEDING METHODS

Self-pollination studies were made with carrots grown under cages. The cage found most satisfactory for the purpose was the so-called Vilmorin type. This is constructed in the following way: A galvanized cylinder 10 to 18 inches in diameter and about 12 inches high is partly sunk in the ground about the carrot plant. A 6-foot stake, to which is fastened one or more wire hoops about 2 feet in diameter, is driven inside the cylinder. A muslin bag open at both ends is pulled down over the stake and hoops and tightly secured to the cylinder at the bottom. The top is tied so that it can be opened readily for examination of the interior.

Twenty Danvers Half Long carrots were grown in cages as described above. In ten of these, freshly emerged flies were placed when the first umbels were in flower. These flies were reared at Davis according to the method described by Jones and Emsweller (2). Additional flies were introduced from time to time so that these cages were kept well populated throughout the flowering period of the plants. Flies were not introduced into the cages of the other plants. In all cages having flies a very good crop of seed was produced. In the ten cages without flies, several plants bore no seed whatever, and only a few seeds were matured on the others.

Cheesecloth was also tried as a material for covering the cages but its use was abandoned when it was found that insects collected wherever the umbels touched the cloth. The subsequent development of seed on these outer umbels indicates that they were probably pollinated by insects working on the outside. Insects did not visit the muslin bags, probably because of their much closer weave.

Attempts were also made to secure self-pollinated seed from single

caged umbels. Wire frames were constructed large enough to hold a single umbel. These frames were covered with muslin bags and were held in position by fastening them to a stake driven into the ground beside the plant. Thirty umbels were enclosed in this manner. In half of the cages flies were maintained during the period of receptivity of the stigmas: those remaining were left without flies. In all cases both with and without flies, no seed was set.

The explanation of this failure to set seed is based on an understanding of the devolpment of the carrot flower. As has been described elsewhere (1) the anthers of carrot flowers dehisce several days before the stigmas are receptive. Very shortly after dehiscence the entire stamen falls from the flower. Although all of the flowers in one umbel do not open at exactly the same time, our data indicate that under conditions at Davis even the latest lose their stamens before the earliest become receptive. It also appears that the pollen probably loses its vitality soon after it is shed because, although it remained in the bottom of the cages and was probably carried to the stigmas by the flies, no seed was set. Under these circumstances, setting of seed on single umbels is not to be expected, even with pollinizing insects present.

This failure to secure self-pollinated seed from single caged umbels to which flies had been added pointed the way to a simple method of making crosses. Twenty umbels of the Danvers Half Long variety were caged individually just prior to anthesis. After dehiscence was completed on each, and when the appearance of the stigmas indicated receptivity, an umbel of the variety Yellow Belgian, with the first flowers open, was introduced into the cage. It was kept from wilting by placing the severed peduncle in a flask of water which was fastened to the stake supporting the cage. This kept it alive long enough to produce pollen during the entire time the stigmas on the female parent were receptive. Here again, flies were used as the pollinating agency, and in all cases an excellent set of seed was secured. The Danvers Half Long and Yellow Belgian were chosen because of their diverse characteristics. Yellow Belgian is light yellow, very long, and grows partly out of the ground, while the Danvers Half Long is an orange colored carrot of medium length growing almost entirely below ground. We felt reasonably certain that some one of these three characters of the Yellow Belgian would be sufficiently dominant or intermediate to those of the Danvers to enable us to recognize the hybrids with reasonable certainty.

Seed from this cross was harvested in August and planted immediately. At the same time, open-pollinated seed from the maternal parent was planted in an adjacent row. A few roots from each row were pulled the first of December. All those coming from the open-pollinated seed were typically Danvers in color, while those resulting from the other lot were distinctly Yellow Belgian, both internally and externally. This indicates a hybrid origin of these roots and shows that crossed seed can be secured without emasculation by introducing foreign pollen after the anthers of the female parent have all dehisced. This method provides an abundance of seed with a mini-

mum amount of work and without the mutilation of flowers involved in emasculation. The plan is to repeat this work in 1934 but much more extensively.

In our inbreeding experiments with several different varieties we have found a very high degree of self-fertility. We have found no case of proven self-sterility. It has been necessary, however, to bag either the entire plant or a portion thereof bearing a number of umbels in various stages of development and to employ flies as pollinizing agents.

Results of inbreeding Danvers Half Long, Coreless, and Nantes indicate that there is a pronounced loss of vigor in the first inbred generation. The effects of inbreeding upon vigor, however, are difficult to interpret because comparisons might be made between early (fast growing) and late (slow growing) strains of equal vigor. In our studies all strains were planted on the same date and those of the same variety that were to be compared were harvested on the same date. Such characters as size and weight of roots and tops attained at this time are taken as a measure of vigor of each strain.

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The Effect of Varying Amounts of Potash on Grade and Yield of the Porto Rico Sweetpotato[1]

By J. H. BEATTIE, and J. D. McCOWN, *U. S. Department of Agriculture, Washington, D. C.*, and E. E. HALL, *Pee Dee Experiment Station, Florence, S. C.*

INTRODUCTION

IT is a matter of common belief that relatively large amounts of potash increase the yield and give a larger proportion of marketable size sweetpotatoes. Work carried on at the Pee Dee Experiment Station during 1921 to 1926 with duplicate plots showed apparent differences between low and high potash applications up to 9 per cent but the nature of the data was such that definite comparisons could not be made: In 1929 an experiment with quadruplicate plots receiving 500 pounds per acre of 3–8–3, 3–8–6, 3–8–9, 3–8–12, and 3–8–15 fertilizer was started at the Pee Dee Experiment Station, and continued through 1931. Each plot consisted of six adjacent 90-foot rows 4 feet apart with the plants 1 foot apart in the rows. The replicates were separated from each other by a total distance of about 72 feet.

TABLE 1. EFFECTS OF DIFFERENT AMOUNTS OF POTASH UPON YIELD OF DIFFERENT GRADES OF SWEETPOTATOES AT FLORENCE, S. C., 1929–1931

Fertilizer Treatment	Yield (Pounds)			
	Jumbo	No. 1	No. 2	Total
1929				
3-8-3	36 ± 5.57	316 ±14.88	54 ± 3.90	406 ±14.32
3-8-6	46 ± 3.70	320 ± 6.68	54 ± 7.38	420 ± 9.52
3-8-9	61 ± 7.86	349 ±21.04	68 ± 8.60	478 ±17.92
3-8-12	56 ± 3.72	396 ±22.75	47 ± 2.95	499 ±22.78
3-8-15	45 ± 4.36	368 ±24.65	50 ± 4.03	463 ±23.47
1930				
3-8-3	46 ± 4.62	535 ± 54.5	135 ±13.6	716.5±46.55
3-8-6	53 ± 6.20	564 ± 53.2	136 ±12.8	752.7±47.42
3-8-9	96 ±13.22	529 ± 47.6	148 ± 8.0	772.7±51.95
3-8-12	98 ± 8.09	525 ± 38.2	128 ± 3.57	750.5±43.15
3-8-15	81 ± 3.70	530 ± 25.5	108 ±12.07	719.0±22.02
1931				
3-8-3	44.5± 5.37	173.0 ± 8.73	51.0± 2.75	269 ±12.11
3-8-6	50.5± 4.07	171.5 ±12.10	54.0± 3.19	276 ±15.77
3-8-9	81.7± 5.28	158.25±10.49	52.0± 2.27	292 ±17.26
3-8-12	81.7± 3.78	130.5 ± 2.56	48.0± 3.42	261.0± 5.51
3-8-15	87.0± 5.66	119.75±10.29	38.0± 4.30	245.0±15.38

[1]A report of a study carried out cooperatively by the United States Department of Agriculture and the South Carolina Agricultural Experiment Station.

The fertilizer was applied under the rows and thoroughly mixed in about 1 week before planting. Plants were set as near May 15th each season as weather conditions permitted, and the crop was harvested promptly after frost had killed the leaves, usually about October 20th. The sweetpotatoes were plowed out, graded as Jumbo, No. 1, and No. 2, and weighed. Records for the four inside rows only were taken but the data are calculated for the entire plot containing approximately 1/20th acre.

Discussion of Results

Table I gives the mean yield in pounds of each grade from the various quadruplicate treatments for the 3 years of each grade per plot with the corresponding probable error of the mean determined by Bessels formula.

The significance of these results is further brought out in Table II which gives Student's odds for the differences between means for 3 years.

TABLE II—Comparison of Yields of Various Grades of Sweetpotatoes from Plots Receiving 3, 6, 9, 12, and 15 Per Cent Potash. Yields and Differences Expressed as Means of Quadruplicate 1/20 Acre Plots. Florence, S. C. Three Years Combined

Treatments Compared		Yield of Different Treatments Compared (Pounds)		Differences (A–B)	Odds of Significance
A	B	A	B		
		No. 1			
3-8-3	3-8-6	341.3	351.8	10.5	Infinitesimal
3-8-3	3-8-9	341.3	345.3	4.0	1.68:1
3-8-3	3-8-12	341.3	350.5	9.2	2.16:1
3-8-3	3-8-15	341.3	339.2	— 2.1	Infinitesimal
3-8-6	3-8-9	351.8	345.3	— 6.5	1.68:1
3-8-6	3-8-12	351.8	350.5	— 1.3	Infinitesimal
3-8-6	3-8-15	351.8	339.2	—12.6	2.16:1
3-8-9	3-8-12	345.3	350.5	5.2	1.68:1
3-8-9	3-8-15	345.3	339.2	— 6.1	1.68:1
3-8-12	3-8-15	350.5	339.2	—11.3	4.86:1
		Total			
3-8-3	3-8-6	463.8	482.9	19.1	10.9 :1
3-8-3	3-8-9	463.8	514.2	50.4	666.0 :1
3-8-3	3-8-12	463.8	503.5	39.7	48.5 :1
3-8-3	3-8-15	463.8	475.6	11.8	2.16:1
3-8-6	3-8-9	482.9	514.2	31.3	48.5 :1
3-8-6	3-8-12	482.9	503.5	20.6	14. 9:1
3-8-6	3-8-15	482.9	475.6	— 7.3	1.68:1
3-8-9	3-8-12	514.2	503.5	—10.7	2.84:1
3-8-9	3-8-15	514.2	475.6	—38.6	Infinitesimal
3-8-12	3-8-15	503.5	475.6	—28.9	1.68:1

Considering the oversize or jumbo grade, the difference in yield between the 3 and 6 per cent potash was not significant but aside from

this there were highly significant differences between the 3 and the 6 per cent potash plots and between the 3 per cent and those receiving higher proportions of potash. The differences between 6 per cent and higher amounts were significant but increasing the potash applications above 9 per cent gave no significant differences from the 9 or 12 per cent plots. Increasing the proportion of potash up to 9 per cent obviously caused an increase in the yield of oversize sweetpotatoes.

Of the No. 1 size there were no significant differences in yield between the plots receiving low and high potash applications. Under the conditions of this experiment which was conducted on soil which had received fairly liberal fertilizer treatment during the preceding years nothing was gained in applying the higher amounts of potash because number one or marketable size sweetpotatoes are the ones desired and the yield of these was not increased by the higher potash applications.

Number two size sweetpotatoes showed no significant increases, and significant decreases in yield between only the 9 and the 12 per cent potash plots, and between the 9 and 15 per cent plots. As there was an increase in the proportion of oversize sweetpotatoes as the rate of application of the potash increased and no significant change in No. 1's this decrease in No. 2's partly offsets the effect on total yield of the increase in jumbos.

In total yield significant increases were produced by the 3–8–9 and the 3–8–12 over the 3–8–3 and by the 3–8–9 treatment over 3–8–6. It has been shown that there was no significant increase in the yield of No. 1's and the increase is attributable largely to the heavy increase of oversize roots.

Table III shows the mean yield in pounds and the proportion of each grade expressed on a percentage basis. This table is of interest chiefly because it shows the increase in the proportion of oversize roots as the rate of application of potash was increased, the decrease in No. 2's, and that there was practically no effect on the proportion of No. 1's. While there was some effect on total yield chiefly with the 9 and 12 per cent potash mixtures it has been shown that this was due chiefly to the increase in the proportion of oversize sweetpotatoes.

TABLE III—Weight and Per Cent Jumbo, Number 1 and Number 2 Sweetpotatoes in Relation to Total Yield for All 3 Years. Florence, S. C.

Treatment	Jumbo		No. 1		No. 2		Total	
	Weight (Pounds)	Per Cent	Weight (Pounds)	Per cent	Weight (Pounds)	Per cent	Weight (Pounds)	Per Cent
3–8–3	42.0	9.05	341.3	73.58	80.0	17.24	463.8	100
3–8–6	49.8	10.31	351.8	72.85	81.3	16.83	482.9	100
3–8–9	79.5	15.46	345.3	67.15	89.3	17.36	514.2	100
3–8–12	75.2	14.93	350.5	69.61	74.3	14.75	503.5	100
3–8–15	71.0	14.92	339.2	71.32	65.3	13.73	475.6	100

Conclusions

These results are at variance with those of most other studies of this problem in the Atlantic States. They are important not because they cast doubt upon previous work, but because they emphasize the danger of attempting too sweeping an application of findings that appear to be generally true. Obviously, under these particular conditions potash was not a limiting factor and money spent for it in large amounts would bring no adequate return.

Despite no profitable increase in yield there is apparent a tendency for high potash to increase the size of the Porto Rico sweetpotato.

Sweet Potato Propagation as Affected by Temperature and Character of the Bedded Roots

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THIS experiment was carried out last spring in three electrically heated hotbeds and one unheated bed of standard construction. Each bed was 6 x 6 feet and the three heated ones were each equipped with 60 feet of lead-covered heating cable. Soil was banked against the outside of the hot-bed frames as a precaution against temperature fluctuations. The temperatures were controlled by means of thermostats of approved design which were set for 95, 85, and 75 degrees F. The unheated bed served as a check.

Selected roots of the Porto Rico variety were bedded March 24 and covered with 2 inches of soil. The roots were divided into four classes designated as large, medium, small and long, and the approximate average weights of individual roots in each group were 14, 8, 4 and 5 ounces respectively. Part of the medium-sized roots and all of the large ones were halved longitudinally and other lots of both medium and small-sized roots were soaked in water over-night before bedding. Altogether eight different lots of sweet potatoes were included in each of the four beds. Since it seemed desirable to allow more room than is ordinarily given, only 10 whole roots (or 10 halves) of each lot were placed in a bed, except in the case of the small size where 16 specimens were used.

Soil and air temperatures were checked three times daily. These determinations indicated that the temperatures were being maintained near the desired point. Some variation was unavoidable, when the increasing warmth of late spring made it impossible to hold the temperatures of the check and 75 degree beds at the proper level. The amount of heat supplied to the 95 degree bed was not quite sufficient to maintain this temperature during the early part of the test as is indicated by the average reading of 93 degrees for the soil temperature of this bed. On the whole, however, it was possible to maintain the temperatures within narrow limits by careful attention to ventilation.

Four pullings of plants were made from each heated bed as follows: 95 and 80 degree beds, April 11, 17, 25, May 9; 75 degree bed, April 17, 25, May 9, 22. Only three pullings were made from the check bed: May 9, 22, and June 13. At the time of the last pulling, the roots in this bed had practically discontinued production of new sprouts and it did not seem worth while to continue the experiment.

Table I shows the average soil and air temperatures in the different beds, the number of days required for the appearance of the plants above ground, the time necessary to produce plants for the first pulling, and the number of days required to grow the plants for four pullings.

The short time required for the plants to appear above ground in the two warmest beds as well as the production in these beds of four

pullings of plants within a period of 46 days shows the rapidity of propagation possible under favorable conditions.

TABLE I—RELATION OF HOT BED TEMPERATURES TO THE NUMBER OF DAYS REQUIRED TO PRODUCE SWEET POTATO PLANTS

	Temperature of Beds			
	95 degrees F	85 degrees F	75 degrees F	Un-heated
Air temperature outside (degrees F)	67	67	69	72
Soil temperature under sash (degrees F)	93	84	79	73
Air temperature under sash (degrees F)	91	82	80	78
Days required for plants to come up	7	8	12	22
Days required for first pulling	18	18	24	46
Days required for four pullings	46	46	59	81*

*Only 3 pullings from this bed.

In Table II is shown the number of plants, per pound of roots, produced by the different lots of sweet potatoes in each of the four beds.

TABLE II—NUMBER OF PLANTS PER POUND OF SWEET POTATO BEDDED

	95 degrees F Bed	85 degrees F Bed	75 degrees F Bed	Check Bed	Average
Large, halved	42	48	48	21	40
Medium, halved	54	79	50	25	52
Medium, halved, soaked	49	66	49	34	50
Medium, whole	40	80	44	39	51
Medium, whole, soaked	37	63	64	42	52
Small	52	79	75	55	65
Small, soaked	49	78	97	60	71
Long	61	104	76	42	71
Average	48	75	64	41	57

Although the results obtained from the individual lots of sweet potatoes at the different temperatures are variable, they show a definite trend in favor of the 85 degree temperature. Rotting of the bedded sweet potatoes particularly those which had been halved, was less at this temperature than in the other beds and the plants produced were larger and stockier than those grown in the 95 degree bed. The latter were spindling and tender and started slowly when transplanted to the open. The plants from the 75 degree and check beds were shorter and more stocky than those produced at the higher temperatures.

While many sweet potato growers produce good plants without artificial heat, these and other tests made by the writers indicate that where earliness is important, or where it is desired to secure the

largest number of plants possible from a given quantity of seed stock; a temperature of about 85 degrees F should be employed.

With regard to the character of the bedded sweet potatoes, the results given in Table II as well as other observations not reported, support the conclusions of Beattie and Thompson (1) that small roots produce a greater number of plants per bushel than do large roots. Halving the medium-sized sweet potatoes before bedding, a practice followed by growers when large roots are used, did not increase the number of plants in the tests here reported. In a preliminary test made in the greenhouse, however, with a soil temperature of 85 degrees F large whole sweet potatoes yielded only 59 plants per pound of bedded roots whereas the halved roots yielded 83 plants per pound. Halved roots were found to sprout more quickly. Further comparisons of seed treated in this manner will be made.

Beattie and Thompson found that cutting the roots crosswise into two or three pieces increased the number but reduced the size of the plants produced. They also found rotting to be a serious factor when the roots were sectioned. Similar observations were made in this work, however, both reduction in size of plants and rotting was less marked when the roots were halved longitudinally than when cut crosswise. It was also observed that there was less rotting at 85 degrees F than at the other temperatures.

In several tests, soaking the sweet potatoes in water prior to bedding has resulted in earlier germination and greater plant production when the beds were maintained at relatively low temperatures, but has not had such effect at the higher temperatures. It has some promise as a practical measure and will be tested further.

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The Effect of Date of Planting on the Shape of Porto Rico Sweet Potatoes

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THE variation in shape of sweet potatoes within a variety has been of interest and also somewhat of a puzzle to sweet potato growers and investigators. Results in New Jersey (2, 3) with the Jersey type of sweet potato, indicate the importance of potash, and also of nitrogen, if chunky potatoes are to be grown. Carolus (1) in Virginia, working with the Porto Rico variety was unable to find an appreciable affect on shape due to applications of potash or nitrogen. For the past 4 years the writers have been conducting a fertilizer test with the Porto Rico variety of sweet potatoes, but have been unable to obtain any affect on the shape of the potatoes from nitrogen and potash applied, although the application of these elements gave increases in yields. Werner (4) in Nebraska found that variations in water supply seemed to have some affect on the shape of potatoes. The varieties he worked with were Nancy Hall and Yellow Jersey.

In 1931 the writers, while working on a storage problem with sweet potatoes, noticed that there was a marked difference in the shape of early planted and late planted potatoes. Those from the early planting were characteristically chunky in shape while the late planted ones tended to be long. When similar results were obtained in 1932, one thousand roots each of the early and late planted lots were measured so as to obtain the length/diameter ratio. The early planted lot was grown from slips and the late planted one from vine cuttings and it was thought that this might have had some influence on variations in shape obtained. In 1933, early and late plantings were made with both vine cuttings and slips. In 1932, measurements were made on potatoes as they came from graders in the field. The following year length measurements were made on the portion of the root that was 0.5 inch or more in diameter. This was thought to give a truer measure of the potato itself, as ends of roots are not snapped in the field to a uniform diameter. One thousand roots each from early and late planted lots were measured in 1933. The L/D ratio when used in this paper means length/diameter ratio. Only the Porto Rico variety of potatoes and only those that graded U. S. 1 were used in the work. The early and late planted lots were grown in similar soil and given the same fertilizer treatment and cultural practice.

Results of measurements obtained for 2 years are shown in Table I. The data presented in Table I show that the length, diameter ratio varied with the date of planting. The differences were of such magnitude that early and late planted lots could easily be distinguished by their characteristic shapes. Environmental conditions were evidently responsible for the variations in shape obtained, but the one that exerted the greatest influence is as yet undetermined. There was some variation between crops of the two seasons, as is evident if the

results of the 2 years are compared. This is partly explained by difference in measurements previously mentioned, but very probably was due in part to the variation in times of planting and to differences in the two seasons. There was 35.79 inches of rainfall from May to November in 1932 compared with 22.38 inches in 1933.

TABLE I—EFFECTS OF DATE OF PLANTING ON THE SHAPE OF THE PORTO RICO VARIETY OF SWEET POTATOES

Time of Planting	L/D Ratio	Av. Length (Cm)	Av. Diameter (Cm)
Early, May 6, 1932.....	1.57±0.014	12.14	7.74
Late, July 15, 1932.....	2.78±0.024	17.15	6.16
Early, April 20, 1933...	1.33±0.023	10.72	8.06
Late, June 15, 1933.....	2.23±0.039	13.79	6.18

In order that the actual variation in shape of early and late planted potatoes may be more clearly shown, Table II is given. Here the number of potatoes found in certain L/D ratio range groups are shown. If one decimal place is pointed off, the number of potatoes given becomes the percentage in each group. The L/D ratio of 24.5 per cent of the early planted lot was 1 or less as compared to 0.3 per cent of the late planted lot. These potatoes were of a distinctly flat turnip shape. The L/D groups through that of 1.5 contained 70.2 per cent of the early potatoes while 86.8 per cent of the late potatoes were above this ratio. This makes very evident the fact that the early potatoes were much more chunky in shape than the late ones. This is shown also in Fig. 1.

TABLE II—LENGTH/DIAMETER RATIO DISTRIBUTION OF EARLY AND LATE PLANTED SWEET POTATOES IN 1933.

L/D Ratio	Less Than 1	1	1–1.5	1.5–2.5	2.5–3.5	Above 3.5
Planted early—number of potatoes	179	66	457	269	27	2
Planted late—number of potatoes	2	1	129	555	240	73

There is a common opinion among growers that sweet potatoes produced from slips are more chunky in shape than those produced from vine cuttings. The data given in Table III show a comparison

TABLE III—COMPARISON OF SHAPE OF SWEET POTATOES PRODUCED FROM SLIPS AND VINE CUTTINGS

Time of Planting	Potatoes from Slips		Potatoes from Vine Cuttings	
	No. of Potatoes Measured	L/D Ratio	No. of Potatoes Measured	L/D Ratio
Early......	564	1.33	565	1.33
Late.......	209	2.26	294	2.21

of the L/D ratios of potatoes grown from slips and vine cuttings planted both early and late. No difference between the two were found, but the shape of potatoes from both varied with the time of planting.

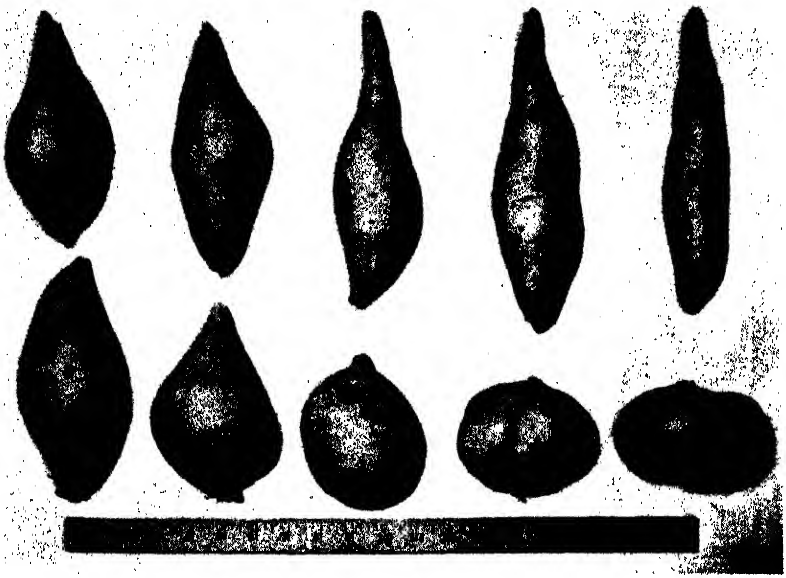

FIG. 1. Lower row—potatoes from early planted lot. Upper row—potatoes from late planted lot.

The results presented in this paper may be used as a possible explanation as to why sweet potatoes are so variable in shape. On the individual hill there may be considerable variation, especially if planted early. The observations of the writers are that in general the more chunky potatoes set first nearest the surface of the soil, and that the longer potatoes set on lower nodes later. It is possible that environmental conditions are favorable for the earlier set potatoes on a hill to be chunky and for later ones to be longer. This may explain the variation in shape of potatoes on the same hill. Many attempts have been made to obtain chunky or long potatoes by selecting these types for propagation, but results in general have been disappointing. This can probably be explained by the likelihood of the variation in shape being due to climatic factors rather than to generic changes.

The practical application of the effect of time of planting on the shape of sweet potatoes is that the grower may control the shape of the potatoes to a considerable extent by the time of setting the plants in the field.

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Natural Cross-Pollination in Lettuce

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WHILE it is conceded that natural crossing may occur it is generally believed that lettuce is almost entirely self-pollinated. Tracy (1) says, "Lettuce does not readily cross-fertilize in the field and different varieties are planted side by side with little danger of mixture." Jones (2) concludes that, "The lettuce flower is almost entirely self-pollinated." Morse (3) makes the statement that lettuce does not cross readily but that there is some evidence of crossing.

While there is a general agreement that very little cross-pollination occurs in lettuce there seems to be no experimental evidence recorded. The winter's observations of progenies from unprotected field-grown plants at the Arlington Experiment Farm, Virginia, during the season of 1931 indicated that some cross-pollination had occurred. For the last 2 years a study has been made to determine to what extent cross-pollination occurs, if at all. The genetic behavior of populations from seed of plants known to be homozygous for certain factors for leaf color were used in determining the extent of natural crossing. A selection from the French variety White Chavigne having green leaves without pigment and a selection from the variety Mignonette having red pigmented leaves were used. Both of these stocks were known to be homozygous for leaf color, their genetic behavior was known and it had been previously demonstrated that the presence of pigment was dominant to its absence. Only pigmented plants were known to result in the F_1 if flowers of White Chavigne were fertilized with pollen from Mignonette.

During the seasons of 1932 and 1933, ten plants of each variety were grown side by side without protection from insects. The plants of each variety were alternated so that each plant of White Chavigne was between two plants of Mignonette. The plants were placed just far enough apart that the lateral branches of the seed stalks did not touch. The plants of each variety were selected from a large lot so as to obtain plants in a similar stage of physiological development in order that both varieties might flower at the same time.

At maturity the seed of each plant was carefully harvested and cleaned by hand. The seed of White Chavigne being white and that of Mignonette black it was possible to avoid any mixing in the handling of the two lots of seed. Populations were grown from seed of each of the 10 green plants of White Chavigne grown each year making a total of 20 populations for study. The extent of crossing which had occurred was determined by counting the number of pigmented plants occurring in each population. Past experience in the study of pigmentation in lettuce leaves had shown that the pigmented plants could be readily distinguished from those without pigment when the plants had developed four or five true leaves if the plants were subjected to relatively low temperature.

The percentage of pigmented plants varied from 1.33 to 6.22 in the 20 populations. The results are given in Table I.

TABLE I—PIGMENTED PLANTS OCCURRING IN POPULATIONS FROM WHITE CHAVIGNE

Plant No.	Parent Color	Progeny Color		Pigmented Plants in Per Cent of Population
		Green	Pigmented	
			1932	
1	Green	233	7	3.00
2	Green	400	7	1.75
3	Green	662	15	2.27
4	Green	514	11	2.14
5	Green	523	12	2.27
6	Green	680	14	2.06
7	Green	840	17	2.02
8	Green	603	8	1.33
9	Green	497	9	1.81
10	Green	928	19	2.05
Total...		5,880	119	Average 2.02
			1933	
1	Green	370	23	6.22
2	Green	732	19	2.59
3	Green	453	26	5.74
4	Green	727	27	3.71
5	Green	710	15	2.11
6	Green	637	19	2.98
7	Green	470	11	2.34
8	Green	509	7	1.38
9	Green	243	6	2.47
10	Green	345	5	1.45
Total...		5,196	158	Average 3.04
Total 2 years..........		11,076	277	Average 2.50

The lettuce flower generally opens early in the morning and remains open only a short time, from ½ to ¾ of an hour. The involucre then closes never to open again. However, there are cool cloudy mornings following a relatively cool night when lettuce flowers remain open for several hours. If insects are active at such periods there is ample opportunity for cross-pollination to occur. During the course of this investigation two species of small insects laden with pollen were noted at various times visiting open lettuce flowers. A number of these were captured and identified as *Halictus zephyrus* and *Halictus sp.*[1]

It is not assumed that these results indicate the extent of natural crossing that occurs generally since the conditions in this case were made favorable. However, they do indicate that the extent of

[1]The identification was made by the late C. H. Popenoe, Division of Truck Crop Insects, Bureau of Entomology, United States Department of Agriculture.

natural crossing may be greater than is generally believed and emphasize the necessity of protection from insects where selfing is desired.

The general uniformity of most of the common lettuce varieties indicates that crossing in the commercial production of lettuce seed must be limited in amount.

It is the writer's observation that practically all commercial stocks of lettuce seed produce at least a small percentage of large, vigorous non-heading plants. It seems probable that most of these are the result of cross-pollination.

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Further Studies Relative to Fertilizer Treatment of Lettuce

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LAST year (1) data were published showing influences of fertilizer treatments on lettuce head production in 1931 and 1932 and on seed production in 1932. The same plots and treatments were used again in 1933 to obtain further evidence regarding production and germination of seed as influenced by fertilizer treatments. The soil is a light sandy loam that was first put into cultivation in 1920. Plots were 15 by 100 feet with duplicate treatments of N, NP, NPK, PK, and manure with single treatments of P and K and seven check plots. Phosphorus and potash in forms of treble-superphosphate and potassium sulphate respectively were applied annually at the rate of 160 pounds each of P_2O_5 and K_2O per acre. Ammonium sulphate was applied at the rate of 120 pounds of nitrogen in 1930 and 1931, and 180 pounds in 1932 and 1933. Sufficient dry corral manure was used to supply nitrogen in amounts equivalent to the inorganic applications. The New York No. 12 strain of lettuce was again employed in these studies. The rows were 18 inches apart with plants 15 inches apart in the row. Irrigation water was applied uniformly and passed through one plot only.

RESULTS

Weight of plants, yield and size of seed:—In late August in 1932, one hundred plants per plot and in 1933, fifty plants per plot were harvested and the seed threshed. In 1933, twenty-five plants representative of the plot were selected and weighed on July 8, the time of normal heading for the best plots. The data are shown in Table I.

The plants on all plots to which nitrogen was applied were significantly larger than plants receiving no nitrogen. Likewise, plants receiving nitrogen and phosphorus combined as NP, NPK or manure were consistently larger than those receiving only N or NK. The yield of seed was greatest from plants receiving both N and P, although the yield from N alone or NK was very much greater than the yield from Check, P, K, or PK plot. In 1933 manure plots receiving an amount of nitrogen equivalent to that received by the other N plots more than lost the advantage they had held prior to that time over inorganic NP or NPK plots. The differences in yield of seed were primarily due to a greater number of flowers produced although plants receiving nitrogen had larger, plumper seeds than did the other plants. The NP plots produced the largest seed in both 1932 and 1933.

The percentage germination of all seed samples was 98.5 or higher indicating that under the conditions of the experiment no fertilizer treatment had a significant effect upon germination notwithstanding differences of 25 per cent in size of seed. Seedlings from lots of large

seed, however, seemed to have more vigor and made a longer growth in 72 hours than did seedlings from small seed. These differences may not be significant in influencing emergence in the field.

TABLE I—YIELD RECORDS AND SIZE OF SEED FROM LETTUCE FERTILIZER PLOTS

Plot	Treatment	Ave. Wt. per Plant (Gms) 1933	Yield Seed per Plant (Gms) 1932	Yield Seed per Plant (Gms) 1933	Wt. 1000 Seeds (Gms) 1932	Wt. 1000 Seeds (Gms) 1933
1	P	113	—	8.8	—	.8348
2	Check	122	—	9.3	—	.8348
3	K	140	—	7.9	—	.8100
4	N	230	14.8	17.7	1.0510	.9112
5	Check	108	8.0	5.9	.9226	.8078
6	NP	631	22.4	24.2	1.0730	1.0234
7	NK	240	23.5	19.4	1.0366	.9948
8	Check	118	5.5	5.9	.8524	.9646
9	NPK	402	23.7	17.6	1.0760	.9570
10	PK	99	9.3	6.6	.9218	.8244
11	Check	63	5.2	5.9	.8924	.7824
12	Manure	325	28.4	18.2	1.0474	.8964
13	N	226	13.2	12.8	1.0090	.8770
14	Check	104	10.2	9.4	.9470	.8348
15	NPK	452	22.2	28.8	1.0670	.9896
16	NP	325	22.7	28.1	1.1186	1.0012
17	Check	63	6.1	6.9	.9298	.8800
18	PK	63	10.0	8.1	.9740	.8206
19	NK	258	18.1	13.4	.9832	.9170
20	Check	81	10.4	5.8	.9686	.7976
21	Manure	344	25.7	18.5	1.0414	.8928

DISCUSSION

Nitrogen continued to be the chief limiting factor since no beneficial response from any other element or combination was found without the addition of nitrogen. Phosphorus and potash applied alone or combined failed to benefit plant responses. Nitrogen and phosphorus combined gave greatest increases over check plots in size of plants, yield, and size of seed, but did not influence seed germination. The plots receiving N in the form of barnyard manure in amounts equivalent to inorganic N received by other plots failed to hold their former advantage over NP and NPK plots. This seems to indicate that under the conditions of the experiment organic fertilizers were not necessary for the successful production of lettuce, and that inorganic fertilizers containing the needed elements were satisfactory. The fertilizer applications had no apparent relation to germination of seed when mature seed was used even though considerable increases were obtained in yield and size of seed from some of the treatments.

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Earworm Damage in Sweet Corn Varieties

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CONTRARY to the opinion of some there is no lack of appreciation in the South of the true sweet corn. Starchy grained roasting ear corn is grown in its place, however, for the simple reason that the farmer by sad and long experience has found that it possesses a greater resistance to damage by the corn earworm, *Heliothis obsoleta* (Fabr.). This resistance to damage is present to a high degree in many field corns, and is due to the long tight husks of such corns, as shown by Phillips and Barber (1).

In the variety tests of sweet corns at the Winter Garden substation in Southwest Texas in the years 1931 and 1932, the ravages of the corn earworm were disastrous to many varieties. Marketable ears were unobtainable (in most cases the kernels and cob had become a slimy pulp) in the following varieties and strains: Early Market, Alpha, Early Surprise, Spanish Gold, Golden Gem, Golden Early Market, Early Sunshine, and Golden Sunshine. Nearly all the other well known white and yellow varieties grown in the North were almost as badly damaged yielding only occasionally a marketable ear. Certain varieties were promising in that they had much larger numbers of usable ears, and these were grown again in 1933 in order to study in greater detail how the types of damage seen in the ears varied with the variety of sweet corn.

From the 77 varieties and strains grown in 1931, and the 52 grown in 1932, 22 strains were selected for test in 1933. With one or two exceptions all the varieties had shown at least a little promise in the previous tests. Wherever sufficient seed was available the samples were planted in three systematically placed replications. Each replication consisted of three rows 30 feet long and 3 feet apart. Plants were thinned to stand 24 to 30 inches apart. As the ears reached the stage of edible maturity they were harvested and examined for corn earworm damage. With a few of the early varieties this examination was made just after edible maturity on some of the ears. Every ear of marketable size in the field was examined. Corn earworm infestation was recorded in one of four classes: 1. No infestation; 2. Injury in silk only; 3. Injury to tip; 4. Injury beyond tip.

All varieties had anywhere from 86 to 100 per cent of the ears infested in some manner or another, and only three of the strains had less than 90 per cent. Infestation seemed to be very much a matter of chance, and as the data show, ran very high irrespective of strain. The type of damage, however, varied much according to the variety. Replications, almost without exception, gave remarkably uniform results, indicating a fairly even infestation thruout the field, so that no variety was less subjected to attack than others.

In Table I which summarizes the data collected from the three replications, the *percentages of infested ears* injured in the various ways are given. This is of especial significance because it indicates

the differences in injury to the ears which were actually subjected to corn earworm attack. It is interesting to note in this connection that two of the varieties which happened to have less than 90 per cent of their ears attacked suffered severely as regards the ears which *were* so infested. Further it should be noted that two varieties, Honey June and Surcropper Sugar, which had somewhat less than the average of ears free from infestation, had very noticeable percentages of their ears marketable due to fewer ears being damaged beyond the tip. Under conditions of normal infestation, a variety resistant to severe injury becomes very important.

The term "marketable" has been used. In this study any ear of desirable size and maturity which was not injured beyond the tip was considered marketable. Hence in Table I the percentages of ears

TABLE I—Record of Earworm Damage to Sweet Corns at Winter Haven, Texas, 1933

Variety‡	Total No. Ears Examined	Percentage Free From Infestation	Percentage Marketable	Ears Infested			
					Percentage damaged		
				Number	In Silk Only	In Silk and Tip	Beyond Tip
Honey June	132	4.5	84.8	126	7.1	77.0	15.9
Surcropper Sugar	124	4.8	73.3	118	2.5	69.5	28.0
Money Maker (Field corn)	172	5.2	52.3	163	1.2	48.5	50.3
Oregon Evergreen	209	12.9	48.8	182	0	43.4	56.6
Redgreen Hybrid*	61	9.8	45.9	55	0	40.0	60.0
Country Gentleman, No. 1	169	6.5	35.5	158	1.9	29.1	69.0
Country Gentleman, No. 2	206	8.7	36.4	188	1.6	28.7	69.7
Golden Sunrise, No. 1	149	1.3	30.9	147	0	29.9	70.1
Extra Early Beverley	125	4.8	32.8	119	0	29.4	70.6
Whipple's Yellow, No. 1	161	3.1	28.0	156	0	25.6	74.4
Golden Sunrise, No. 2	155	3.8	27.7	149	0.7	24.8	74.5
Golden Bantam, No. 1	159	8.8	28.3	145	0	21.4	78.6
Country Gentleman, No. 3	168	11.3	29.8	149	6.0	14.8	79.2
Golden Bantam, No. 2	73	4.1	21.9	70	0	18.6	81.4
Golden Bantam, No. 3	72	8.3	23.6	66	0	16.7	83.3
White Sunrise	120	9.2	24.2	109	0	16.5	83.5
Whipple's Yellow, No. 2	123	6.5	21.1	115	0	13.9	84.3
Buttercup	110	3.6	13.6	106	0	10.4	89.6
Kingscrost Golden Bantam*	36	13.9	22.2	31	0	9.7	90.3
Spanish Golden*	11	0	9.1	11	0	9.1	90.9
Stowell's Evergreen, No. 1†	78	1.3	7.7	77	0	6.5	93.5
Stowell's Evergreen, No. 2	108	0.9	5.5	107	0	4.7	95.3

*Only one replication. †Only two replications.

‡Varieties have been listed in order of merit based on their resistance to corn earworm damage as indicated in the column "Beyond Tip"; the lower the percentage the greater the merit.

marketable include all those ears which were: (a) free from infestation; (b) injured in silk only; and (c) injured in tip, but *not* beyond.

It has been said that most of the varieties in the 1933 test had shown at least a little promise in the trials of 1931 and 1932. As the performance of the older well known varieties in 1933 was very much like that of the previous years, it can be seen how little this promise was from the commercial point of view. In most cases the failure of those omitted from the 1933 trials had been wholly or partly due to corn earworm damage, altho other factors, such as general vigor, plant and ear size, etc., did enter in. It must not be assumed that adaptability of sweet corns to Southwest Texas is entirely dependent on their resistance to corn earworm damage.

The data collected in 1933 indicate that next to the new sweet corns Honey June and Surcropper Sugar, Oregon Evergreen ranks high as an established commercial sort so far as resistance to earworm damage is concerned. Its record of 56.6 per cent ears damaged beyond the tip places it far behind Honey June in actual score, however. This variety was noted as one of the most promising of the commercial varieties for the Winter Garden region in the seasons of 1931 and 1932. Money Maker, which has a rating higher than Oregon Evergreen, is a starchy kerneled roasting ear corn. Both have fairly tight husks, which unfortunately usually lack length, as compared with more resistant varieties. Red-green Hybrid, a white sweet corn of high quality, followed Oregon Evergreen closely in rating. Two strains of Country Gentleman, a variety having a fair reputation for resistance to corn earworm damage came next, each having very nearly 70 per cent of their ears damaged beyond the tip. The 15 other varieties and strains all had 70 or more per cent of the ears severely damaged. Two strains of Stowell's Evergreen were the most badly damaged of the entire collection and contrasted rather strikingly with Oregon Evergreen.

Checks to this work at Winter Haven were furnished by the junior author who made similar records in addition to egg counts of *Heliothis obsoleta* on six varieties of sweet corn at College Station, over 300 miles to the east of the Winter Garden substation. The records show that irrespective of the season or the type of the variety, oviposition did not occur on any variety to any great extent until the silking began on that variety, when an abundance of eggs were found. This agrees with the findings of Phillips and Barber in their studies of corn earworm injury to field corns (1). The per cent of marketable ears is shown in Table II.

It will be noticed that Honey June and Surcropper Sugar both rated well, with the latter excelling the former by 1 per cent. Stowell's Evergreen showed up much better in this particular test in which it rated third. However, in other tests at four substations in Texas in 1933, Stowell's Evergreen has shown considerably more damage than in the tests at College Station. This was more in line with the test at Winter Haven. Honey June and Surcropper Sugar all indicated a high resistance to corn earworm damage in every one of these trials. Both varieties have been developed by Dr. P.C. Manglesdorf of the

Texas Agricultural Experiment Station, who also supplied the information with reference to the tests on the other substations.

TABLE II—PERCENTAGE MARKETABLE EARS OF DIFFERENT VARIETIES

Variety	Number of Ears Examined	Per cent Marketable
Surcropper Sugar	410	99
Honey June	385	98
Stowell's Evergreen	440	83
Country Gentleman	405	63
Golden Bantam	521	44
Spanish Gold	460	0

Honey June comes from a cross between Country Gentleman and Mexican June. While it appears especially adapted to Southwest Texas, it also has brought forth favorable comments from many sections in the South, some outside of Texas. The stalks are taller than those of most sweet corns, and often produce two marketable ears. The fairly large ears possess tight fitting long husks, which give the variety its remarkable resistance to corn earworm damage. Ears have 12 to 16 rows of white kernels. It is a true sweet corn, approaching, but hardly equalling, Country Gentleman in quality.

Surcropper Sugar has as its parents Surcropper field corn and Country Gentleman sugar corn. It resembles Honey June in having long tight husks. At the present time it fails to equal Honey June in uniformity of characters, and in sweetness of kernel, altho in some locations it has excelled Honey June in resistance to earworm damage and in productiveness.

Early in the season considerable quantities of roasting ears are shipped North from Texas. Altho such ears have been of the starchy type, they have been large, and hence today the demand is for large ears. Because Honey June and Surcropper Sugar possess large attractive ears closely resembling in type the sort of roasting ear which is shipped North, it is believed that as seed of these varieties become more available they will be grown more and should satisfy the buyer who has become accustomed to look for large ears.

The study of earworm damage to sweet corns conducted last summer indicates that the same factors, *viz.,* long, tight husks, which have been shown by Phillips and Barber (1) to be so important in limiting damage to field corns, are likewise of great importance in the protection of sweet corns. Since the varieties which showed the greatest resistance were those recently developed with that idea in mnid, we can have renewed hopes concerning the prospect of true sweet corns for the South. Not only do we know what types are liable to be successful, but the corn breeder has already begun to produce them.

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The Influence of Planting Depth on the Shape of the Scarlet Globe Radish[1]

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MANY growers and certain seedsmen believe that relatively deep planting of Early Scarlet Globe radish seed induces the development of comparatively long, slender roots. Since according to these growers, slender, elongated roots are less preferable on the market than the more rounded, globular forms, definite information on the influence of planting depth seems highly desirable. The results of certain tests conducted at State College, Mississippi, are reported herein.

The experimental area, consisting of a moderately fertile Ocklocknee clay loam, was 15 feet long and 2 feet 4 inches wide. On October 20 it was deeply spaded, thoroughly raked, smoothly surfaced, and divided lengthwise into six equal parts to permit the growing of two strains (542 and 92, U. S. Seed Co.) alternately in systematically triplicated plots.

Two depths of planting were used, a relatively shallow depth (0.5 in.) and a relatively deep depth (1.5 in.). They were secured by pressing edgewise into the level surfaced soil ¼ inch strips either 0.5 inches or 1.5 inches wide. These depths were alternated and the rows were made 4 inches apart. Seed was planted ⅛ to ¼ inch apart. Water was supplied whenever necessary to maintain adequate soil moisture except from November 13 to November 17 when the soil became rather dry. Harvests were made on November 10, 17, 24, and December 8. At this time most of the seed had matured edible roots.

To obtain an index to root shape, measurements were made of the length and width of the roots. Since many roots gradually tapered to a point, length was measured from the basal part of the crown to a point on the lower end of the root not greater than 2 millimeters in diameter (estimated). Width was measured from the widest part of the diameter from which the two rows of lateral roots appeared. The ratio of the length and width was calculated for individual roots and is considered an index to root shape. A comparatively large ratio indicates an elongated root and a comparatively small ratio a roundish or globular shaped root. All measurements were made with vernier calipers.

For comparative purposes both the arithmetic (M) and geometric (M_g) means, together with the probable errors of the individual ratios, were calculated. Crist (1) states that statisticians are agreed fully that the geometric mean is more reliable than the arithmetic mean for use with ratios. The probable error of the geometric mean

[1]Under the direction of the writer, Messrs. J. A. Davis, G. B. Head, H. D. McMorrough and W. T. Smalley, senior students in horticulture, outlined the experiment and measured the roots in partial fulfillment of the requirements in their laboratory work in advanced vegetable gardening. Published with the permission of the Director of the Mississippi Agricultural Experiment Station.

was determined according to the following formula derived by Kelly for calculation of probable errors of geometric means of price indices.

$$PE_{M_g} = \frac{0.67458\ M_g}{n} \sqrt{\frac{1}{r_1^2} + \frac{1}{r_2^2} - - - - \frac{1}{r_n^2}}$$

Where n= the total number of individuals and r= an individual ratio.

TABLE I—INFLUENCE OF PLANTING DEPTH ON THE SHAPE OF THE SCARLET GLOBE RADISH. 1933. (STRAIN 542. U. S. SEED CO.)

Planting Depth (Ins.)	Number Roots	Average Diameter (Cms)		M_a[1]	M_g[2]
		Length	Width		
		Harvested November 10			
1.5	64	2.352	1.190	2.040±.0409	1.972±.0435
0.5	118	2.050	1.402	1.495±.0096	1.446±.0105
Difference (1.5 minus 0.5)		0.302	−0.212	*0.545±.0410	*0.526±.0447
		Harvested November 17			
1.5	20	2.430	1.149	2.184±.0777	2.123±.0805
0.5	58	2.166	1.192	1.846±.0340	1.808±.0354
Difference (1.5 minus 0.5)		0.264	−0.043	*0.338±.0849	*0.315±.0880
		Harvested November 24			
1.5	71	2.807	1.297	2.220±.0403	2.160±.0427
0.5	59	2.331	1.333	1.751±.0304	1.708±.0356
Difference (1.5 minus 0.5)		0.476	−0.036	*0.469±.0504	*0.452±.0556
		Harvested December 8			
1.5	56	2.644	1.440	1.890±.0306	1.843±.0322
0.5	27	2.420	1.686	1.398±.0408	1.351±.0415
Difference (1.5 minus 0.5)		0.224	−0.246	*0.492±.0510	*0.492±.0563
		November 10 to December 8			
1.5	211	2.558	1.269	2.084±.0202	2.021±.0216
0.5	262	2.242	1.403	1.627±.0157	1.558±.0186
Difference (1.5 minus 0.5)		0.316	−0.134	*0.457±.0256	*0.463±.0285

[1]Arithmetic mean of individual ratios.
[2]Geometric mean of individual ratios.
*Differences are considered significant.

The probable error of the arithmetic mean and that of the difference between means was determined according to standard formulae. A difference greater than three times its probable error is considered significant.

The data presented in Table I show that in all cases seed planted 1.5 inches deep produced roots possessing a greater length and a lesser width than seed planted 0.5 inches deep. This correspondingly greater length and lesser width resulted in a greater length/width ratio for the roots grown from the deeper planted seed. In all cases the differences are considered significant.

The consistent relation between the arithmetic and geometric mean is striking. In all cases each arithmetic mean was higher and its probable error was lower than the corresponding geometric mean and its probable error. Consequently, the difference betwen two geometric means should have lesser significance than that between two corresponding arithmetic means.

Similar results were obtained with Strain 92 (data not given) grown in alternate plots with Strain 542. For all harvests the 1.5 inch planting produced roots with a greater length and a lesser width than the 0.5 inch planting. For all harvests except that of November 17, when a comparatively small number of roots were measured, the differences are significant. Significantly similar results were obtained also with Strain 3212 (U. S. Seed Co.) grown from September 30 to November 3 in sand in the greenhouse. Apparently, a consistent relation exists between planting depth and root shape. Relatively deep planting promotes the development of a more elongated root than relatively shallow planting. Since the round, globular type is preferred to the more elongated type, growers should give depth of planting due consideration.

TABLE II—DIFFERENCES IN ROOT SHAPE BETWEEN STRAINS 542 AND 92 (U. S. SEED CO.) OF SCARLET GLOBE RADISH GROWN FROM OCT. 22 TO NOV 8, 1933

Strain	Average Diameter (Cms)		M_a[1]	M_g[2]
	Length	Width		
	Planted 1.5 inches			
542	2.558	1.269	2.084±.0202	2.021±.0216
92	2.249	1.349	1.720±.0184	1.658±.0192
Difference (542 minus 92)	0.309	−0.080	*0.364±.0274	*0.363±.0289
	Planted 0.5 inches			
542	2.242	1.403	1.627±.0157	1.558±.0186
92	2.007	1.413	1.439±.0307	1.401±.0421
Difference (542 minus 92)	0.235	−0.010	*0.186±0.345	*0.157±.0461

[1]Arithmetic mean of individual ratios.
[2]Geometric mean of individual ratios.
*Differences are considered significant.

Table II presents data showing the differences in root shape between the two strains. Regardless of planting depth Strain 542 produced roots with a greater length and a lesser width than Strain 92.

Though the differences are considered significant in both cases, they were greater for the deeper planting. Apparently, strains of the Scarlet Globe radish differ in shape of the root as measured by the length/width ratio. Apparently, the deeper the planting the greater the difference.

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Seasonal Variation in the Tenderness of Asparagus

By John H. MacGillivray, *Purdue University, Lafayette, Ind.*

EXPERIMENTAL work was planned to study factors causing toughness in asparagus. Conditions have resulted in the work being curtailed, but a satisfactory method for determining tenderness has been adopted. The commonly used apple tester was used with a modified plunger. A morphological study of the lignification and increase of fibre after cutting has been made by Bisson, Jones and Robbins (1).

The green asparagus used for these tests was of the Martha Washington variety and the field was 10 years old. The soil was a clay silt loam of medium fertility. The plants had been given average care and fertilization, and was representative of commercial fields not in extremely high vigor.

Individual spears were tagged as they came thru the ground and cut when over 7 inches in length. The spears were taken immediately to the laboratory where the resistance to pressure was measured by means of an apple pressure tester (2) having a plunger ⅛ inch in diameter and ⅜ inch in length. Tests were made at 2, 4, and 6 inches from the tip, and the last 2 years at 5 inches from tip after the outside portion of the stalk had been removed by scraping with a knife. This removed the lignified pericycle fibres and exposed the inner whitish tissues.

These experiments were not conducted under controlled conditions and, consequently, the reasons for the variation are not distinct. It is usually believed that asparagus just before cutting ceases is much tougher than earlier in the season. This may be commonly true, but in 1931 the results in Table I indicate a reverse of this condition. On the first day in 1931 there was an average resistance of 3.3 pounds as compared to the average of 4.1 pounds for the first third of the season. The base of the spear is usually tougher than the tip and the middle portion is tougher than the tip. In the large number of individual determinations made, it was possible to find all kinds of exceptional relationships. Either the tip or middle can be tougher than the remaining parts in isolated cases, or the tip and middle can be tougher than the base. The readings obtained on the scraped portion indicate more tenderness, but about the same variation in tenderness, one part of the season with the other, as in the unscraped.

There seems a very small variation in the temperature comparing one season's average with another, but there were significant differences in amount of rainfall. Twenty years' average rainfall for Lafayette up to and including 1931 is 38.7 inches per year. The annual rainfall in 1929 was 51.3 inches; in 1930 it was 30.6 inches; in 1931 it was 35.6 inches; and in 1932 it was 36.4 inches. The 1930 crop received the most rain during the cutting season and also was preceded by a year of heavy rainfall. The plants received a small amount

TABLE I—MEAN PRESSURE RESISTANCE OF ASPARAGUS DURING DIFFERENT PERIODS OF THE SEASON (POUNDS OF RESISTANCE)

Dates	Height of Puncture Test (Inches)				Average	Number of Stalks	Average Temperature (Degrees F)	Rainfall (Inches)	Average Diameter (Mm)
	2	4	6	5*					
1930									
4/21–5/6	2.38±.068	2.64±.052	3.05±.101	———	2.69±.052	32	57.3	1.45	15
5/7–5/21	2.84±.054	3.05±.054	3.58±.098	———	3.15±.045	22	63.0	1.67	17
5/22–6/5	3.25±.060	3.26±.068	4.29±.156	———	3.60±.073	75	64.2	.31	15
1931									
4/22–4/30	3.63±.079	3.73±.084	5.01±.180	3.00±.112	4.10±.098	24	45.6	.44	11
5/1–5/10	3.51±.055	3.62±.065	4.91±.260	2.05±.132	4.04±.122	112	53.7	.92	11
5/11–5/20	3.17±.062	3.34±.049	3.70±.079	2.03±.062	3.41±.046	113	60.6	1.05	11
1932									
5/5–5/14	2.49±.053	2.48±.041	2.97±.072	1.63±.107	2.65±.033	283	62.4	1.78	11.6
5/15–5/23	2.75±.050	2.70±.039	3.78±.113	1.88±.035	3.07±.029	248	63.1	.04	10.6
5/24–6/1	2.52±.062	2.47±.054	3.74±.150	1.73±.056	2.91±.073	97	67.5	.04	9.9

*Lignified pericycle removed by scraping with knife.

of rainfall during the beginning of the cutting season of 1931 and the spears were the toughest tested. The plants received a high rainfall at the beginning of the season of 1932, but little after the first third of the cutting period.

A correlation of $r = .313 \pm .019$ indicates that as the number of days required to produce a 7 inch spear increases there is a slight increase in toughness or resistance to pressure. The correlation of $r = .199 \pm .020$ indicates that as the spears harvested had an increased diameter there is a very slight increase in toughness. These coefficients of correlation are based on the 3 years' results of 1006 spears.

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The Relation of Bulb Size to the Thickness of the Outer Scales in the Onion

By J. E. Knott, *Cornell University, Ithaca, N. Y.*

THE vigor of growth of the onion bulb is thought by some to be an important factor in determining the thickness of the outer scales. The yield on the muck soils of New York that produce bulbs with thin, poorly-colored scales is not materially different from the yield on those soils giving well-colored bulbs. This would indicate that there may not be a definite correlation between bulb size and scale thickness.

In connection with greenhouse experiments on the effect of minerals on the color and thickness of onion scales, data have been obtained on other factors that influence scale thickness.

The scale thickness was measured with a micrometer at the point of greatest diameter of the bulb. The coefficients of determination between vigor of growth, as represented by the green weight of the bulb, and the thickness of the first complete dry scale are given in Table I. Each represents a population of 90 to 100 bulbs grown in triplicate containers of muck receiving the treatments indicated, in addition to an application of 1,000 pounds an acre of 3–12–18 fertilizer. Ebenezer sets were used on treatments 1 to 6 inclusive, and Red Wethersfield sets on 7 and 8. "Good color muck" indicates the soil that produces bulbs of good color and "poor color muck" that on which the scales were poorly colored.

TABLE I—The Coefficient of Determination Between Size of Bulb and Thickenss of the First Complete Dry Scale

Treatments	Crop of Oct. 8, 1932 to April 19, 1933 (Per cent)	Crop of April 29, 1933 to July 3. 1933 (Per cent)
"Good-color muck"		
1. No sulfate added	0.045	5.272
"Poor-color muck"		
2. No sulfate added	0.00008	0.995
3. Cobalt sulfate	0.003	0.102
4. Zinc sulfate	0.009	0.223
5. Nickel sulfate	0.011	0 001
6. Copper sulfate	0.017	0.115
7. No sulfate added	0.0007	0.319
8. Copper sulfate	0.031	0.029

The bulbs in the first crop attained three times the weight of those of the second crop. Late planting and high temperature in the greenhouse in June caused the second crop to ripen prematurely. However, the thickness of scale of the two crops was approximately the same under the respective treatments. With the average scale thickness constant and the average bulb size diminished, the coefficient of

determination was increased in most cases. The bulbs on the "good-color" muck were smallest in the second crop, but even here only 5 per cent of the increase in scale thickness is associated with bulb size. This approaches the 7 per cent reported previously (1).

The data as a whole show that there is little association between the size of the bulb and the thickness of the outer scales.

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Thrips Resistance in *Allium cepa*

By H. A. Jones, S. F. Bailey, and S. L. Emsweller, *University of California, Davis, Calif.*

Abstract

This paper will appear in the University of California Hilgardia series.

The Relative Firmness of Fifteen Onion Varieties

By Roy Magruder, and E. Q. Knight, *U. S. Department of Agriculture, Washington, D. C.*

THE relative firmness of different varieties of onions is detectable by squeezing in the hand. In order to secure a measurement of these differences, two types of instruments were used in studies carried on in 1933 at the Arlington Farm of the U. S. Department of Agriculture.

Materials and Methods

The onions for this study were all grown at Arlington Farm for the Vegetable Variety Standardization and Description project. They matured during the month of July, were cured rapidly in a greenhouse, and stored at air temperatures until the readings were made. Neck rot was quite prevalent and the interval between harvest and measurement allowed time for it to develop. Only sound representative bulbs of the proper varietal type were selected for the measurements.

Some preliminary tests using the $^{5}/_{16}$-inch diameter tip on the most recent modification of the Magness and Taylor fruit pressure tester, showed that this plunger was too large for use on the hardest variety. A tip ⅛-inch in diameter proved satisfactory and by steady pressure was forced into the onion tissue $^{5}/_{16}$-inch deep at eight points along the line of greatest diameter perpendicular to the growth axis. Four of these readings were made through the dry outer scales and four at points between the dry scale readings after the dry scales had been removed and counted. In removing the dry scales a horizontal cut through them, ¼- to ½-inch long was made one-half inch above the line of greatest diameter. The dry scales were then stripped down to the root plate, thus exposing the succulent tissue. Since the bulbs were 2¼ to 2¾ inches in diameter the readings were from 1 to 1½ inches apart. Readings were made on September 12, on only 10 sound bulbs of each variety picked at random in the indicated size range.

The pressure or squeeze testers illustrated on page 330 of the 1932 proceedings of this society was also used to test firmness. The plunger moved through ½-inch and scales calibrated in pounds instead of grams were used. Two pressure readings were made on each bulb at right angles to each other and at the point of greatest diameter with the plunger perpendicular to the growth axis. The bulbs were graded by size into the three or four size classes listed in Table II and the readings made between September 27 and October 2; about 2 months after harvesting. When possible, readings were made on 50 bulbs of each size. In the 2½- to 3-inch class, this number was not available except for Ebenezer, Mountain Danvers, Red Wethersfield and Sweet Spanish. The average number tested for the other varieties was 31.2 with a range of 15 to 47.

Results

Puncture tests with the fruit pressure tester were not carried beyond the preliminary stage since the tests with only 10 bulbs indicated that this test was not a good measure of solidity. The successive layers of scales made it difficult to get an accurate reading because of the "jump" in pressure as each outer epidermis of the succeeding scales was encountered. The four readings of the succulent flesh on a single bulb varied quite widely due no doubt to the relative stage of desiccation of the outer fleshy layer. A study of the readings from single bulbs shows in general a progressive decrease and increase in pressure as one goes around the bulb indicating that one side dries down quicker than the other. Dissection of several bulbs also showed this to be true.

In several cases the reading without dry scales was higher than with the dry scales in place. It was also noted that occasionally a bulb which would be classed as slightly soft by squeezing in the hand would give a higher reading than one which was quite firm. In these cases it was evident that the turgid cells of the hard bulb offered less resistance to the small plunger than those of the softer bulb.

The relative dryness or brittleness of the dry scales also varied widely and affected the readings. In general the varieties with scales which adhered relatively tightly to each other, required the greatest pressure to penetrate. Those scales which had loosened from the bulb as in the case of Yellow Bermuda, California Early Red and Red Wethersfield were more brittle and easier to penetrate.

TABLE I—Resistance of 10 Onion Varieties to $\frac{5}{16}$ Inch Penetration by $\frac{1}{8}$ Inch Diameter Plunger. Pressure in Pounds. Average of Four Readings on Each of 10 Bulbs

Variety	Bulbs with Dry Scales		Difference	Dry Scale Number		
	Attached	Removed		One	Two	Three
Yellow Bermuda	4.97	3.59	1.38	10	—	—
California Early Red	5.06	3.39	1.67	9	1	—
Red Wethersfield	4.63	3.88	.75	9	1	—
Mountain Danvers	5.52	4.09	1.43	3	5	2
Yellow Globe Danvers	5.81	4.07	1.74	3	5	2
Ohio Yellow Globe	6.27	4.37	1.90	1	5	4
White Portugal	6.79	4.42	2.37	1	7	2
Southport White Globe	8.58	5.00	3.58	5	3	2
Sweet Spanish	8.62	4.67	3.95	3	5	2
Australian Brown	9.61	6.25	3.36	2	7	1

Although the data are based on four readings from each of only 10 bulbs they are presented in Table I and seem to indicate that the flesh of Australian Brown is firmer and that of Yellow Bermuda and California Early Red softer than that of the other varieties listed and that the dry scales of Australian Brown, Sweet Spanish, Southport White Globe, and White Portugal offered more resistance to puncturing than

those of the other varieties. Within a given variety the condition of the dry scales was more important than the number in influencing the pressure required to penetrate although in general the pressure required increased as the number of dry scales increased.

The pressure or squeeze tester was much easier to use, the onions could be used for other purposes after testing and the readings more nearly represented a test of firmness than the puncture readings given by the Magness and Taylor type of instrument.

The onions were graded into three and in one variety into four, diameter-classes in order to determine whether there was any difference in firmness of different size bulbs from the same crop. The small size of the probable error (Table II) indicates that the bulbs were remarkably uniform in firmness, only an occasional soft bulb being encountered. In general, differences of less than .25 pound between the means are not statistically significant, using five times the probable error as a criterion of significance. In the few cases where significant differences occur, the largest onions are usually harder than the smaller ones.

TABLE II—Pressure Readings in Pounds on 15 Onion Varieties with ½ Inch Movement of Plunger

Variety	Diameter of Bulbs (Inches)		
	1¾ to 2¼ (Pounds)	2¼ to 2½ (Pounds)	2½ to 3 (Pounds)
Yellow Bermuda	13.55±.0450	13.85±.0473	13.93±.0524
California Early Red	14.67±.0572	15.13±.0472	15.10±.0913
Yellow Strasburg	15.04±.0473	15.17±.0462	15.36±.0547
White Portugal	15.25±.0315	15.44±.0308	15.41±.0531
Southport Yellow Globe	15.42±.0357	15.29±.0438	15.38±.0521
Red Wethersfield	15.53±.0539	15.32±.0424	15.40±.0433
Mountain Danvers	15.34±.0361	15.47±.0313	15.70±.0336
Ebenezer	15.40±.0385	15.69±.0386	15.78±.0340
Southport White Globe	15.71±.0311	15.69±.0343	15.52±.0405
Prizetaker	15.72±.0443	15.54±.0553	15.94±.0480
Southport Red Globe	15.73±.0334	15.86±.0326	15.82±.0499
Yellow Globe Danvers	15.84±.0355	15.82±.0317	15.92±.0545
Ohio Yellow Globe	15.88±.0367	15.89±.0347	15.93±.0458
Sweet Spanish*	15.64±.0396	15.89±.0366	16.09±.0310
Australian Brown	16.67±.0292	16.56±.0307	16.37±.0428

*Three to 3½ inch bulbs 16.34±.0291.

The varieties are arranged in the table in order of firmness based on the average of all sizes. Yellow Bermuda was the softest variety tested and was also significantly softer than the next softest variety, California Early Red. California Early Red was slightly softer than Yellow Strasburg on the average for all sizes. None of the successive pairings except the last, between Sweet Spanish and Australian Brown, show any significant difference in firmness. A difference of 1 pound in the scale reading equals .025 inch difference in compressibility. A difference of 2 pounds between two varieties means that the softer variety was squeezed together .05 inch more than the harder one.

Ratings based on thumb pressure observations placed these varieties in three groups; soft, Yellow Bermuda and California Early Red; hard, all between Yellow Strasburg and Sweet Spanish; very hard, Australian Brown. The results from the mechanical tester corroborate fairly well the personal judgment of hardness. These tests would need to be continued for a number of years to determine the relative standing of the varieties in the hard group. It is of interest to note in this connection, that the varieties in the soft class are notoriously poor keepers or poor storage varieties. Those in the hard class are the varieties grown in the extensive onion sections of the north central United States and commonly stored for winter use while the Australian Brown is the best storage onion for California conditions.

Summary

Preliminary tests with a modified Magness and Taylor fruit pressure tester indicate that it is not as satisfactory for measuring the hardness or firmness of onions as the squeeze tester illustrated on page 330 of the 1932 Proceedings of this Society, although it may be used for measuring resistance of scales to puncturing.

The squeeze tester showed that Yellow Bermuda and California Early Red were the softest, Australian Brown the hardest and our usually stored varieties were in the intermediate class (Table II). There were few significant differences in hardness between the three sizes of the same variety but when differences were significant (although small), the largest size class was usually harder than the smaller ones.

The fruit pressure tester indicated that the dry scales of Australian Brown, Sweet Spanish, Southport White Globe and White Portugal offered more resistance to puncturing than those of the other varieties tested (Table I).

The Influence of Planting Distances on the Yield of Snap and Lima Beans

By W. A. MATTHEWS, *University of Maryland, College Park, Md.*

IT is a prevailing opinion that Refugee snap beans require more space in the row than the variety Burpee Stringless Greenpod because the former produces a more luxuriant growth of vines. Gillis (1) reported results of a 4 year's investigation of distance of planting with snap beans. The crops were grown under various conditions with respect to soil and weather. Maximum yields were obtained with Refugee when spaced 2 inches in the row, while with Burpee Stringless Greenpod a $1^{1}/_{3}$ inch spacing was best. Halsted (2) obtained largest yields of snap beans at a planting distance of 3 inches, this being his closest planting. Jordan's (3) results indicate a positive correlation between close spacing and the percentage of early yield. To the writer's knowledge no data is extant on the subject of lima bean spacing.

MATERIALS AND METHODS

In this investigation commercial strains of Refugee and Burpee Stringless Greenpod snap beans, and Henderson's Bush Lima beans were used. Two plantings of snap beans were made, the first May 31 and the second June 30. The lima beans were planted on the latter date. An excess of seeds were drilled, and plants thinned to 3, 6, 9, and 12 inches apart before the secondary leaves were evident. The growing season was characterized by an abundance of rainfall. Plots consisted of single rows 20 feet long. These were replicated five times, with a distance of 3 feet between rows. The arrangement of plots was according to the Latin square method. They were located at the Weaver Farm, about 3 miles from College Park, on fairly coarse, sandy loam of medium fertility. The beans were hand cultivated as needed, and in harvesting a special effort was made to pick the fruit uniformly with respect to the minimum size. It was found necessary to make three harvests with the variety Refugee, and five harvests with the Burpee snap beans. Three harvests at 3-day intervals were made in the case of the lima beans, removing 1/3 of the plot rows at each harvest. No significant relationship was found between time of harvest and distance of planting, therefore, only combined data for the three harvests are presented.

The results are expressed as: (a) total yield in pounds per plot, (b) per cent early yield, (c) number of beans per plant, and (d) number of beans per pound. The early yield is expressed as the per cent of the total yield secured in the first two harvests. The number of beans per pound was determined by counting two samples of ½ pound each. When less than a pound was available the entire plot harvest was counted. The significance of the data was determined according to Fisher's analysis of variance method. Differences greater than two times the standard error were considered significant.

Results

Total yield:—Table I shows that snap beans of the varieties Refugee and Burpee responded differently to the variations in spacing of plants under the conditions of this experiment. With Burpee the yield significantly increased as the distance between plants decreased. This was true for both plantings. The variety Refugee, however, exhibited difference in yield only between the 3- and 6-inch distances. The fact that the average percentage yield decrease of both plantings between 3- and 9-inch spacings was 44 per cent for Refugee and only 29 per cent for Burpee indicates that the former variety was not as capable of utilizing the space efficiently as the latter. Lima beans of the variety Henderson's Bush responded to plant spacing somewhat similarly to that of Burpee snap beans.

Early yield:—The early yield of Burpee for the 3-inch spacing was significantly greater than that of the 6-inch spacing. In only one case (Burpee planted May 31) did the early yield of the 6-inch spacing prove significantly greater than the 9-inch. The second planting of Refugee and Burpee was comparable. The first planting of Refugee, however, showed a reverse trend although the difference is not significant. The fact that close spacing of bean plants is positively correlated with early yield should be of considerable interest to growers of beans for canning and market purposes.

Number of beans per plant:—As indicated in Table II, there was a consistent increase in the number of fruits per plant as the space between plants increased. However, this increase was not in proportion to the increase in the distance between plants. Both snap and lima beans exhibited in a fairly similar way the above trend.

Number of beans per pound:—The data on number of beans per pound in Table II is fairly uniform. There is a slight indication that plants spaced 6 and 9 inches apart produced beans of a larger size than plants spaced 3 inches apart. This suggests that the beans on plants spaced 6 and 9 inches developed more rapidly during the interval between harvests, although further work is necessary to definitely establish this point.

Discussion

Although data secured on this problem at the present time are limited, it is evident that larger total and early yields result from the 3-inch spacing of both Refugee and Burpee snap beans and lima beans than from wider spacing. This suggests that growers of beans for canning and market purposes should pay particular attention to the matter of planting in order to secure fairly close spacing of plants in the row. Contrary to the results reported by Gillis the yield of the variety Refugee decreased proportionately more with wider spacing than did the variety Burpee, indicating that under the conditions of the test the former was less able to utilize the additional space.

Acknowledgments

The writer wishes to acknowledge assistance extended to him by members of the Department of Horticulture during the course of this

TABLE I—THE INFLUENCE OF PLANTING DISTANCE ON THE TOTAL AND EARLY YIELD OF SNAP AND LIMA BEANS

Distance Between Plants (Inches)	Burpee				Refugee				Henderson's
	Planting Date May 31		Planting Date June 30		Planting Date May 31		Planting Date June 30		Planting Date June 30
	Yield		Yield		Yield		Yield		Yield
	Total (Pounds)	Early (Per cent)	Total (Pounds)	Early (Per cent)	Total (Pounds)	Early (Per cent)	Total (Pounds)	Early (Per cent)	Total (Pounds)
3	10.24	73.94	5.79	49.08	7.37	50.45	6.36	49.03	4.72
6	8.71	67.76	4.80	30.50	4.66	52.86	4.22	33.70	3.87
9	7.66	58.97	3.90	29.19	3.78	55.89	3.93	29.02	3.37
12	—	—	—	—	—	—	—	—	2.66
Dif. 3–6	1.53	6.18	.99	18.53	2.71	2.41	2.14	15.33	.85
Dif. 6–9	1.05	8.79	.90	1.31	.88	3.03	.19	4.68	.50
Dif. 9–12	—	—	—	—	—	—	—	—	.71
Dif. Necessary*	.45	2.46	.71	11.45	1.08	8.53	.66	8.87	.52

*Difference necessary for odds of 19:1 obtained according to Fisher's analysis of variance.

TABLE II—THE INFLUENCE OF PLANTING DISTANCE ON THE NUMBER OF FRUITS PER PLANT AND THE NUMBER OF FRUITS PER POUND

Distance Between Plants (Inches)	Burpee				Refugee				Henderson's	
	Planting Date May 31		Planting Date June 30		Planting Date May 31		Planting Date June 30		Planting Date June 30	
	No. of Fruits		No. of Fruits		No. of Fruits		No. of Fruits		No. of Fruits	
	Per Plant	Per Pound	Per Plant	Per Pound	Per Plant	Per Pound	Per Plant	Per Pound	Per Plant	Per Pound
3	14.14	111	8.76	121	11.53	122	10.97	138	8.61	146
6	23.16	109	15.12	126	13.75	121	12.90	128	13.74	142
9	29.79	105	17.62	122	17.69	119	18.69	136	17.39	139
12	—	—	—	—	—	—	—	—	19.55	147

work. He is indebted to Dr. H. B. Cordner for suggestions in analyzing the data and in preparing the paper, to Dr. J. H. Beaumont for reviewing the paper, and to Mr. W. K. Bailey for assistance in obtaining the data.

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External and Internal Factors Affecting Blossom Drop and Set of Pods in Lima Beans

By H. B. Cordner, *University of Maryland, College Park, Md.*

A STUDY of blossom drop in Lima beans was started at Maryland in 1928 in which both soil and climatic factors have been considered. The results in general have indicated that the yield of pods for uniformly spaced plants is normally quite highly and positively correlated with size of plant and with bearing area as indicated by the number of racemes. Thus widely divergent average yields of pods per plant will result when environmental factors affecting vegetative development are operative. Set of pods per raceme varied less than set per plant. The variations were significant, however, and indicated an association with factors both internal and external to the plant. These factors are probably inter-related and at times it is difficult to definitely identify fruiting responses with either one or the other. The situation is complicated by the production of an excess of blossoms. However, during the course of the study certain data were secured in which the relation of external or internal factors to blossom drop and fruit set was quite definitely indicated. These data serve as a basis for this report.

Procedure

The drop of buds, flowers, and pods in Henderson's Bush:—Sixty uniform plants were selected in a row seeded May 24, 1929. On July 10 five strong determinate racemes, in their first day of blooming, were tagged on each plant. These racemes were examined daily throughout the blooming period and the drop recorded according to the node of the peduncle and the stage of development of the abscissing part. Buds, (prepollination) flowers, and fruits (after petals had fallen) were differentiated. After the blossom period the final set of fruit was recorded with respect to position on the raceme.

TABLE I—The Extent and Nature of the Drop in the Variety Henderson's Bush

Data on 300 Racemes (1929)	Average per Raceme	Per cent of Total
The drop of:		
1. Buds	20.81	39.29
2. Flowers	23.96	45.23
3. Fruits	3.84	7.25
Fruits developed	4.36	8.23
Total	52.97	100.0

The data summarized in Table I indicate that the abscission of buds occurs almost as frequently as the abscission of flowers while rela-

tively little dropping takes place after the petals fall. Inasmuch as these racemes initiated (as an average) almost 53 potential pods it is evident that a great excess of reproductive structures are produced. In fact the average total set of pods on the entire plant was but 55.1 with an average set per raceme of slightly over 2 pods. Thus the strong determinate racemes used set very well in spite of the loss of over 90 per cent of the potential fruits by abscission.

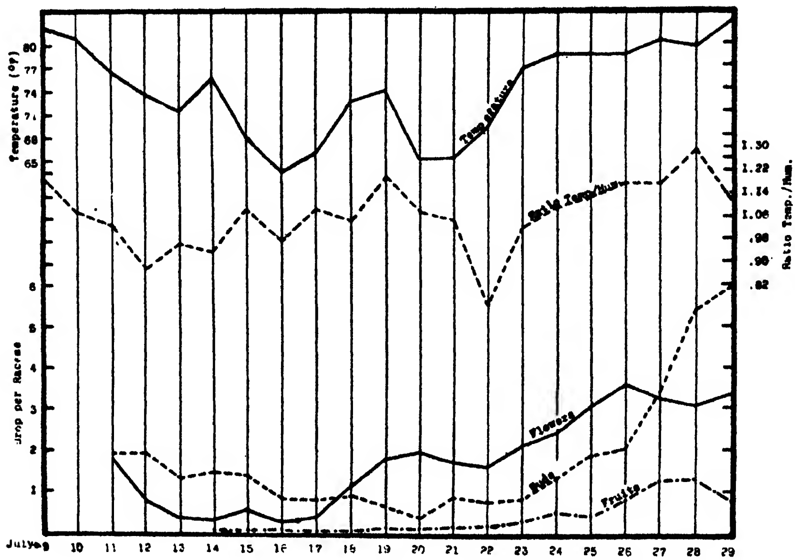

FIG. 1. The daily rate of drop of buds, flowers and fruits in relation to atmospheric temperature and relative humidity

The daily rate of abscission in relation to weather:—The daily drop rates of buds, flowers, and fruits were compared with the daily mean temperature and the ratio, temperature/humidity. It is assumed that a high temperature in association with low relative humidity is conducive to the abscission of blossoms.

The results presented in Fig. 1 indicate that the daily rate of blossom abscission was associated with temperature and possibly humidity. The initial rate in the drop of flowers (July 11 to 13) was higher than would normally be expected of racemes in the early flowering stage. This and other variations in the drop trend for flowers are associated with variations in the temperature curve. The daily rate of bud abscission followed the same general trend as that for flowers. Associated with a decline in the vigor of the raceme, during the late part of the blooming period, fewer blossoms appeared and thus the rate of bud drop markedly increased.

Pod setting and floral abscission in relation to position on the raceme:—The daily drop histories and final set of fruits for four

racemes are expressed diagramatically in Fig. 2. With racemes A and B relatively little abscission of flowers occurred during the first 7 days (July 11 to 18) and a good set of pods resulted on the seven nodes at the base, which were flowering during this period. A great number of blossoms were produced on these racemes and additional fruits appeared after this 7 day period but all were dropped leaving a large number of the nodes barren. This is the usual mode of fruit

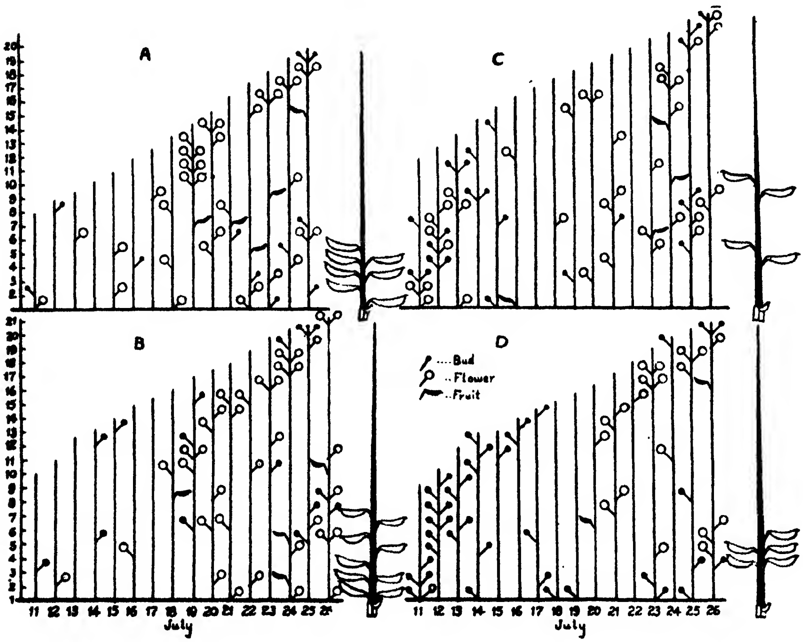

FIG. 2. Diagram illustrating the daily drop of buds, flowers, and fruits and final set of pods on racemes of Henderson's Bush. (Final set to right of daily drop diagram).

setting and it is very probable that the barren nodes in the more terminal portion of the racemes are the result of a peculiar physiological condition established in the peduncle in association with fruit set and development at its base.

Racemes C and D of Fig. 2 apparently followed an abnormal course of development in that a considerable abscission of buds and flowers preceded fruit set, resulting in barren nodes at the base of the racemes. This may have been the result of factors external to the plant. A short delay in fruit setting seems to have reduced the final set in these two racemes.

The position of fruit set modified by defloration:—Three groups of racemes were used. In group 1 all but nodes one to four were kept free of blossoms. In group 2, four consecutive nodes were unmolested in a median position and in group 3 fruit setting was permitted

in four nodes at the terminal and beyond the 12 node. To secure comparable racemes blooming for the first time on the desired nodes of the peduncle at about the same time, groups 3, 2, and 1 were selected on plants of Henderson's Bush seeded May 24, May 31, and June 14 respectively.

TABLE II—THE SET OF PODS OF DEFLORATED RACEMES

Data Secured (1929)	Position of Undeflorated Nodes on Peduncle		
	Base	Middle	Terminal
Number of racemes treated	682	609	542
Average fruits set per raceme:			
1. Fruitful racemes	2.43	2.30	1.72
2. On all racemes	1.88	1.34	0.78
Unfruitful racemes as per cent of total	22.58	41.88	54.68

The final set of pods on these racemes as summarized in Table II show that pod setting can be induced at the terminal nodes of the peduncle in the absence of fruit set, at the base. Normally, few or no pods set on these terminal nodes. The greatest number of pods developed when setting was permitted on basal nodes indicating that these basal nodes are potentially the more fruitful.

The set of fruit on racemes in relation to the time of blooming:—Several varieties of bush and pole types of Lima beans were planted successively on June 8, June 21, and July 5, 1932. Groups of about 20 racemes on the plants of each variety were tagged at intervals throughout the blooming season. Racemes just entering their respective blooming periods were selected for tagging and at harvest the average set of pods was determined. These averages are given in a comparison with the temperature/humidity ration in Fig. 3. The ratio was calculated from means representing the first 6 days of the blooming period.

The racemes of the Henderson's Bush variety showed a marked decline in productivity as the blooming season of the plant advanced with little or no relation between the set of pods and the temperature/humidity ratio. Racemes of Burpee's Bush set fewer pods with a less consistent trend. Data on Fordhook Bush (not given in Fig. 3) was somewhat similar to that for Burpee's.

The trend established by the set of pods on racemes of the Sieva Pole variety is characteristically different from that of the bush varieties, being negatively correlated with the temperature/humidity ratio ($r = .534 \pm .13$). It appears that vigor and productivity are maintained at a uniformly high level over a long period of time in this variety. Thus with the internal factors remaining fairly constant a definite relationship is established between fruit set and certain factors of the external environment.

Discussion

Yield of pods in Lima bean plants depends upon the number of racemes produced as associated with plant size and the average set of pods on these racemes. Plant size is the product of the environment during the pre-bloom period; pod set, as indicated by the data presented, is the product of the environment during the flowering period.

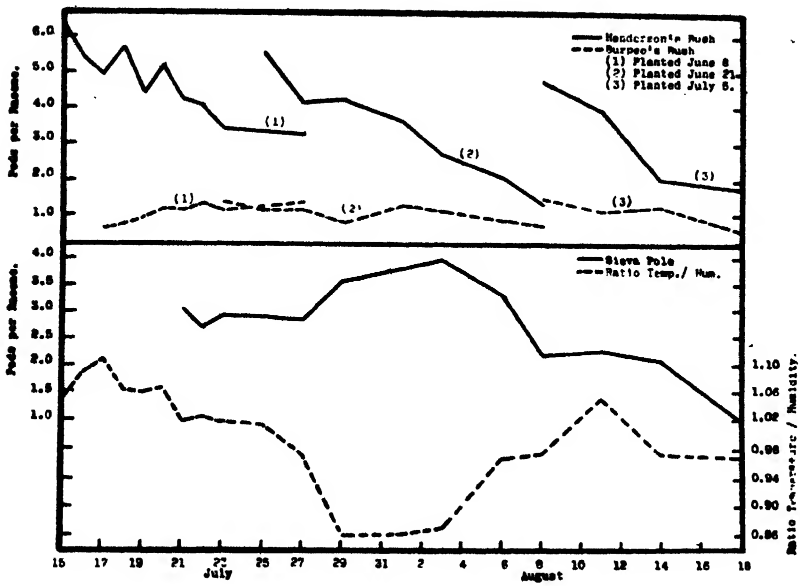

FIG. 3. Set of fruit on racemes in relation to time of blooming and temperature/humidity ratio.

There is no doubt that a great excess of blossoms are produced on the racemes of Lima bean plants and normal flowering and fruiting proceeds as follows: Flowering is initiated at the base of the peduncle and progresses toward the terminal. Fruit setting follows until a "capacity set" is attained; the remaining reproductive structures are disposed of by abscission. Thus pods are produced largely on the basal nodes of the raceme, the terminal part of the peduncle being characteristically barren.

The data presented indicate that racemes of different varieties vary with respect to fruiting capacity on the basis of the number of fruits set. (On the basis of weight of fruits matured this difference is not so great.) It was also indicated that the capacity to set fruit, in racemes of the same variety varies in relation to internal and external factors operative during the blooming period. Early blooming racemes are more productive than late blooming racemes on the same plant in Henderson's Bush. This is probably

associated with the position of the raceme on the plant. The data on defloration indicate that the basal nodes of the raceme are potentially more fruitful than terminal ones.

The results also show blossom abscission to be associated with high air temperature and a dry atmosphere. Whether this proves adverse to fruit set, apparently depends upon the time of occurrence and the duration of the adverse weather. The critical time is in the early part of the blooming period of the raceme. Racemes failing to set at this time are characterized by a low final set. This relation between fruit set and atmospheric conditions is fairly definitely established by the data secured with the Sieva Pole variety.

A similar relationship between weather and blossom drop in snap beans had been suggested by Binkley (1) who also indicated that there was a relation between blossom drop and a fluctuating soil moisture supply.

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Effects of Chlorinated Water on Land Plants, Aquatic Plants, and Goldfish

By P. W. Zimmerman, and Robert O. Berg, *Boyce-Thompson Institute, Yonkers, N. Y.*

Abstract

The complete paper may be found in Contributions from Boyce-Thompson Institute 6 (1): 39–49. 1934.

THIRTEEN species of plants: *Avena sativa* L. var. Clydesdale, *Coleus blumei* Benth., *Coreopsis tinctoria* Nutt., *Cosmos bipinnatus* Cav., *Cosmos sulphureus* Cav., *Fagopyrum esculentum* Moench., *Clycine max* Merr. var. Biloxi, *Hordeum vulgare* L., *Lycopersicon esculentum* Mill. var. Bonny Best, *Nicotiana tabacum* L. var. Burley, *Secale cereale* L., *Tagetes erecta* L., and *Triticum aestivum* L., were watered daily for 3 or more weeks with chlorinated water having a range of 1 to 1000 parts of free chlorine per million of water. None of the species of plants grown in loam soil were injured with chlorinated water having 50 p.p.m. or less of chlorine. Plants watered with chlorine concentrations of 100 to 150 p.p.m. were injured or retarded in growth. Plants grown in sand were retarded in root and top development by solutions containing 5 p.p.m. or more of free chlorine. Cut flowers were not affected with 10 p.p.m. but some were injured with 50 p.p.m. When the solutions were renewed daily, goldfish were killed with 1.5, 2, and 3 p.p.m. Where the water was constantly renewed concentrations of 1 and 1.5 killed the fish. Fantail varieties appeared to be less resistant than the common variety of goldfish and the common variety was less resistant than the Shubunkin variety. Aquatic plants appeared to counteract the toxic effect of chlorinated water on fish. Cabomba and Elodea were injured with 3 p.p.m. after 7 days' exposure. The city water supply tested for chlorine showed frequently 0.5 p.p.m. and occasionally as much as 1.5 p.p.m. It was concluded that the concentration of free chlorine in city water supplies could not injure plants but might injure goldfish, especially if the supply in the aquarium should be constantly renewed.

Tradescantia a Test Crop for Soil Fertility

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

Abstract

To be published elsewhere in full.

Factors Influencing the Growth of Plants in Cloth Houses

By Wilfred George Purdy, *Ohio State University, Columbus, Ohio*

FACTORS which influence the growth of plants under cloth enclosures, namely, light, temperature, relative humidity and the color of the cloth are the subject of this paper.

The cloth used was the standard tobacco cloth which has a 22 by 22 mesh per inch. One-half of the house was of white and the other half of yellow cloth.

Results

Light Intensity:—In 1932, Laurie (1) showed that yellow cloth reduced the intensity of light 12 units, and white cloth 6 to 8 units. He also found that the difference between the amounts of light transmitted by the two cloths was greater when the light intensity was high. For taking these measurements he used a slowly sensitized paper.

In 1933 similar tests were made, using a Weston illuminometer which reads directly in foot candles. These readings give a definite measure of the very marked reduction in the intensity of light which is available to plants growing under cloth. The increased stem length and increased size of plants under cloth may largely be due to this factor.

TABLE I—A Comparison of the Percentage Reduction in Light Intensity

Cloth	Laboratory Conditions		Full Sunlight	
	Foot Candles	Reduction (Per cent)	Foot Candles	Reduction (Per cent)
None	44.7	0.0	11,500	0
White	37.2	16.8	7,475	35
Yellow	32.0	28.4	6,900	40
Red	25.3	42.4	6,035	47.5

Temperature:—On the basis of average temperature readings for 1933, in no case was there a difference of 2 full degrees between the temperature outside and under cloth.

Humidity:—The relative humidity under cloth was very nearly the same as outside early in the morning, but later in the day was slightly higher under cloth.

Conclusions

1. Light intensity was decreased by the use of cloth enclosures.
2. The light intensity under yellow cloth was 5 per cent less than under white cloth, and 7.5 per cent greater than under red cloth.
3. The average temperature was slightly higher under the cloth enclosures.

4. The relative humidity was slightly greater under cloth during the hotter parts of the day; that is, after 10:00 a. m.

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Porous Versus Non-Porous Pots for House Plants

By S. W. Decker, *University of Illinois, Urbana, Ill.*

Abstract

The complete paper will be published elsewhere.

THE relative value of the two types of pots for house plants has been studied from the standpoint of the kind of plant, soil temperature, and the water required to maintain the desired soil moisture.

Gladiolus Studies: Variation in Storage Temperature

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

Abstract

To be published elsewhere in full.

Studies of the Effects of Cheese Cloth Enclosures on the Flower Production, Underground Development, and Rate of Transpiration of Flower Crops

By F. S. Batson, *Ohio State University, Columbus, Ohio*[1]

EXPERIMENTS conducted by Laurie (1) and Post (2) indicate that cheese cloth enclosures are conducive to greater development of plants and the production of higher quality blooms in a number of summer flower crops. Since the climatic conditions in the Southern States cause commercial cut flowers to be very difficult to produce during July, August, and early September, this experiment was conducted to study the responses of flower crops to cheese cloth enclosures under Mississippi conditions.

An enclosure 30 feet x 30 feet x 6 feet was made of yellow reinforced cheese cloth (22 mesh to the inch). Potted seedlings of asters and snapdragons were transplanted to the enclosure and to an adjacent unprotected plot during the latter part of May. No. 3 gladioli corms and dahlias propagated from cuttings were also set in the plots during the early part of June. Asters were allowed to develop without disbudding. Snapdragons were pinched to six stems per plant. Several erect stems were allowed to develop from the base of the dahlia plants. The laterals produced by these stems were disbudded to three blooms per lateral.

The quantity of water applied to the unprotected plot was about twice the amount applied to the enclosed area. Since the evaporation of moisture from the soil in the unprotected area was more rapid, the water content of the soil was often greater under cloth.

Although the difference in relative humidity during early morning and late afternoon was insignificant, it was 5 to 8 per cent higher under cloth from noon to 5 p. m. on clear days. The temperatures varied from 0 degrees to 3 degrees F higher under cloth throughout the summer months.

The data (Table I) show consistent increase in the stem-length of the various crops under cloth. Differences in the number of florets produced per spike are inconsistent. Gladioli show a slight decrease in the number of florets produced per spike under cloth, whereas snapdragons show an increase of 2.5 florets per spike. The average flower diameters of asters and dahlias were slightly greater under cloth. Although the difference in the number of blooms produced per plants is insignificant in the case of asters, the number of dahlia blooms produced per plant was greatly reduced under cloth.

Since the number of dahlia blooms produced per plant under cloth is decreased and since an enclosure more than 6 feet high is necessary for the proper development of the plants, it is not profitable to grow dahlias under cloth.

[1]These data were obtained at the Mississippi Agricultural Experiment Station during the summer of 1933 when the writer was a member of the Experiment Station staff.

TABLE I—EFFECTS OF CLOTH ENCLOSURE ON FLOWER PRODUCTION

Treatment	No. of Plants Used	Av. Length of Stem (Inches)	Av. Diameter of Flower (Inches)	Av. No. Florets per Spike	Av. No. Blooms per Plant
		Gladiolus var. Orange Queen			
Cloth.....	91	22.9	—	13.0	—
Open......	90	18.6	—	13.4	—
		Snapdragon var. Jennie Schneider			
Cloth.....	54	18.2	—	10.8	—
Open......	46	11.6	—	8.3	—
		Aster var. Queen of the Market			
Cloth.....	61	9.4	2.1	—	22.0
Open......	47	6.8	1.9	—	23.6
		Dahlia var. Jersey Beauty			
Cloth.....	25	20.5	5.2	—	22.5
Open......	25	15.3	4.9	—	30.9

All crops, except dahlias, grown under cloth produced stiffer stems and more intense color of blooms. The foliage and blooms of all plants grown under cloth were free of sunscald. This is a decided advantage since sunscald caused considerable injury to plants in the unprotected area. Asters grown under cloth were more resistant to wilt and entirely free of aster yellows. Although rust seriously injured the snapdragons in both plots, the plants under cloth were more resistant.

TABLE II—INFLUENCE OF CLOTH ENCLOSURES ON THE PRODUCTION OF GLADIOLI CORMS

Treatment	No. of Plants	No. Corms Produced	Av. Weight per Corm (Gms)	Per cent No. 1 Corms	Per cent No. 2 Corms	Per cent No. 3 Corms	Per cent No. 4 Corms	Per cent No. 5 Corms
Cloth..	84	87	35.8	89.7	8.0	2.3	0.0	0.0
Open..	90	92	40.2	94.6	2.2	2.2	0.0	1.0

Twenty Clerodendron thompsonae, having from 15 to 30 leaves per plant, were placed in 3-gallon glazed pots, sealed with high melting point paraffin, and a 2-inch layer of dry sand was placed over the paraffin in the tops of the pots. One-half of the plants were placed under cloth and the other half were placed in the open. Weights were taken three times during a period of 10 days. At the end of that time the leaf area of each plant was measured.

The amount of water transpired per square inch of leaf surface was 9.4 ± .20 in the cloth enclosure and 11.6 ± 4.2 in the unprotected

plot. The difference of 2.2 ± .46 may be ascribed, at least partially, to the higher relative humidity in the enclosure.

Acknowledgments

The writer expresses his appreciation to Professor R. V. Lott and Dr. J. B. Edmond for advice in planning the investigation.

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Further Studies with Additional Illumination on Plants in the Greenhouse

By G. H. Poesch, *Ohio State University, Columbus, Ohio*

Abstract

This material will be published in bulletin form by Ohio State University.

Further Studies in Photoperiodism as Applied to the Chrysanthemum

By Alex Laurie, *Ohio State University, Columbus, Ohio*

Abstract

This material will be published in bulletin form by Ohio State University.

Gladiolus Forcing: Effects of Exposure to High Temperatures Before Planting

By E. C. Volz and C. G. Keyes, *Iowa State College, Ames, Ia.*

THE effectiveness of high temperatures in breaking the dormancy of plants has been demonstrated by Müller-Thurgau and O. Schneider-Orelli (4), Loomis (2), and Loomis and Evans (3). The favorable results obtained with gladiolus by Fairburn (1) in some forcing experiments at Iowa State College led to these investigations which had for their chief purposes the testing of many varieties and of giving more consideration to the practicability of forcing gladiolus corms.

Forty varieties of gladiolus, including three varieties of the new upright type and eight of the laciniated type, were used in these experiments[1] with a minimum of ten corms for each variety. On January 17, 1933, five corms of each variety were placed in a chamber regulated to run at 86 degrees F. Uniform moisture was provided by placing the corms on moist sphagnum moss held between burlap. The other five corms of each variety were continued in storage at 50 degrees F. All the corms were planted in a greenhouse bench February 1, 1933. The greenhouse temperature was 50 degrees F at night and 60 to 65 degrees F during the day. The usual cultural practices for greenhouse gladiolus culture were carried out.

The first vegetative shoots from the treated corms appeared above ground 12 days after planting, as compared to 25 days for the untreated corms. As was expected distinct varietal responses were evident. However, the treated corms of most varieties showed development distinctly in advance of those not subjected to the 86 degrees F temperature conditions.

Individual records were kept on each variety for various items, which are summarized in the following table:

	2 Weeks at 86 degrees F	Check 2 Weeks at 50 degrees F
Number of corms used	211	222
Number of corms that grew	211	222
Average number of days to bloom*	100	109
Number of flowers produced in April	25	6
Number of flowers produced May 1 to 15	109	56
Number of flowers produced May 15 to 31	84	148
Number of flowers produced after June 1	22	37
Average number of florets per spike	9	11
Average length of stem	42	43
Number of corms producing 2 or more spikes	59	56

*Average days to bloom in field, 75.

[1]Gladiolus corms used in this experiment were furnished by A. E. Kunderd Inc., Goshen, Indiana.

It is evident from these data that the heat treated corms flowered 8 days in advance of those untreated. This is an average for all 40 varieties included in the experiment. A study of the individual records which are not presented shows that some varieties greatly exceeded this average. The treated corms of the six varieties, Blushes of Cream, Modern Beauty, Mrs. Dr. Norton, Mrs. Paul Dieball, Pink Favorite, and Hyperian, flowered 2 weeks in advance of those not treated. The three varieties C. C. Sherlock, Chas. A. Lindbergh, and King of Oranges showed a difference of 3 weeks in favor of the heat treatment. The data in the table show that 64 per cent, or 134 flowers were produced from the treated samples before May 15, or 14½ weeks after planting. During this same period only 28 per cent or 62 flowers were produced on the untreated samples. It is significant that considerably more flowers were produced from the treated corms before May 15 than from the untreated corms in the same period. There was no apparent difference in the quality of the flowers from the treated and untreated corms. There was an average of nine florets per spike produced by the treated corms and an average of 11 florets per spike by those untreated. The average length of stem, measured from the soil level to the tip of the flower spike, was 42 inches on the treated plants as compared to 43 inches for the plants not treated.

The following varieties other than those mentioned above, forced most readily and produced flower spikes of the highest quality: Golden Tinge, John T. McCutcheon, Lustre, Magic, Miss Bloomington, Torpedo, Impressario, Interlude and Pierian. The four last named varieties and the variety Hyperian previously mentioned were of the upright and laciniated types. As only 11 of these newer types of gladiolus were represented in these trials, it seems reasonable to assume that commercial florists should give some consideration to the upright and laciniated forms in commercial forcing.

When grown under field conditions during the months from May to September the average time from planting to flowering is 75 days for these varieties. In the greenhouse during the period from February to June the average time required for the same varieties to flower was 100 days for heat-treated corms and 109 days for those given no treatment.

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Forcing Gladiolus

By W. E. Loomis, *Iowa State College, Ames, Ia.*

THE pronounced rest period shown by gladiolus corms and the tendency toward "blindness" in forced plants, have been important factors in preventing a more general forcing of this popular flower. Several years ago the author reported with Evans (5) that the gladiolus varieties Halley, Alice Tiplady, Arlon and Le Marechal Foch, had been forced into vegetative growth, and in some cases into flower, by high temperature storage treatments of the type used for certain varieties of Irish potatoes (4). Our results have since been corroborated by Emsweller (1), Emsweller and Tavernetti (2), Fairburn (3), and Volz and Keyes (6).

Additional data on the effect of temperature on the growth and particularly on the flowering of some varieties of gladiolus, are presented here.

Forcing the Germination of Corms

Storage and soil temperatures of 25 to 35 or 40 degrees C (77 to 104 degrees F) have successfully forced the germination of all gladiolus varieties used, namely: Halley, E. J. Shaylor, Arlon, Giant Nymph, Le Marechal Foch, and Alice Tiplady. Other varieties have been forced by Fairburn (3) and by Volz and Keyes (6). Acceleration of germination has varied from 2 weeks, for moderate treatments given late in the season, to 4 months for the most successful treatments on recently dug, Iowa-grown corms. In one series of experiments 40 storage, chemical and soaking treatments with Arlon corms were planted in soil with a temperature of 15 to 20 degrees C (Table I). The first 15 treatments to germinate, and the first 12 to flower were high temperature storage treatments. No treatment other than high temperature storage induced germination in less than 5 weeks, while eight of the high temperature lots germinated in 3 weeks or less. Similarly, of 14 treated lots of Alice Tiplady, all but one among the first seven lots to germinate, and all of the first seven to flower, had been stored at temperatures of 32 degrees C (89.6 degrees F) or higher (Table II). Foch, Shaylor and Halley have responded equally as well to treatments of this sort.

In general, storage treatments of 1 week at 40 degrees C (104 degrees F), 2 weeks at 35 degrees C, 4 weeks at 30 degrees C, 6 weeks at 25 degrees C, or 8 to 10 weeks at 20 degrees C (68 degrees F) have been approximately equal in their effectiveness on recently dug corms. The lower temperatures with the longer exposures are safer, and milder treatments should be used for corms already partly through the rest period. The early-dug California corms frequently used for forcing have received the equivalent of a high temperature storage treatment in their curing and handling.

A number of experiments in which corms have been packed in wet moss during high temperature storage, and a limited number of observations on dormant or partly dormant corms forced by high soil

temperatures (27 degrees C) have indicated that high soil and high storage temperatures are both effective, although the latter are preferable on the basis of cost. Humidity seems not to have been a direct factor beyond the prevention of excessive drying of the stored corms. The chemical treatments used include 2 and 5 per cent (by weight) dip treatments with ethylene chlorhydrin held for 24 and 48 hours after dipping in closed containers, and gas treatments with 1 and 2 ml, 40 per cent ethylene chlorohydrin for 24 and 48 hours. Recently dug corms have not been forced into satisfactory flowering by any of the chemical treatments used. Chemical treatment after a moderate, high-temperature treatment has been effective with some varieties, notably Halley, but not with Alice Tiplady.

The Flowering of Forced Corms

The flowering of forced corms presents problems in part distinct from those of germination, but to a considerable extent tied up with

TABLE I—Flowering of Arlon. (Checks Planted and Treatments Started October 28, 1928)

Treatment	Days, Planting to 50 Per cent Flowering	Date First Flower	Rank, Days to 50 Per cent Germination	Per cent Plants Flowering	Av. No. Flowers per Spike
1 week 40 degrees C	89	1/29	10	80	3.50
4 weeks 40 degrees C wet	92	2/26	5	70	5.00
7 weeks 25 degrees C wet	94	3/19	1	70	6.30
7 weeks 25 degrees C	97	3/19	2	100	7.00
2 weeks 40 degrees C wet	101	2/10	11	80	5.62
7 weeks 30 degrees C	103	3/21	3	90	6.33
7 weeks 35 degrees C	103	3/24	7	100	6.30
4 weeks 35 degrees C	106	2/26	6	60	6.17
4 weeks 30 degrees C	106	3/5	4	60	5.50
1 week 40 degrees C wet	108	2/11	14	80	6.38
Average first 10	99.9	3/2	6.3	79	5.81
2 weeks 35 degrees C	113	2/15	9	80	6.00
1 week 35 degrees C	114	2/10	8	70	5.20
5 per cent dip	119	2/16	19	60	4.50
2 milliliter gas	119	2/10	18	60	4.17
2 weeks 30 degrees C	120	3/5	12	80	5.75
H_2O, 6 hours 40 degrees C	120	2/13	20	80	6.25
7 weeks 5 degrees C	121	4/7	16	130	7.53
2 weeks 25 degrees C wet	127	2/21	13	80	5.62
2 weeks 25 degrees C	127	2/26	15	60	5.67
4 weeks 45 degrees C	132	3/19	17	100	7.00
Average second 10	121.2	2/26	14.7	80	5.77
Average checks	146.0	3/2	27	83	6.92

the breaking of the rest period. Flower bud differentiation in gladiolus occurs soon after new shoot growth starts (3). Differentiation is thus dependent on chemical conditions within the mother corm as well as on the environment of the new plant. We have found a tendency for treatments which do not completely break the rest period, to result in a weak vegetative growth with few flowers, particularly during the winter months.

The best 20 to 40 treatments given Arlon corms are shown in Table I. Arrangement is made on the basis of days in the greenhouse to 50 per cent flowering. Some of the longer storage treatments flowered after the checks, but in a shorter time from planting. The best 12 treatments were high temperature storage. The best chemical treatments, a 5 per cent dip, and a two ml per liter gas treatment with ethylene chlorhydrin were thirteenth and fourteenth respectively. The warm-bath treatment of Müller-Thurgau (6 hours in H_2O at 40 degrees C) was sixteenth. Rapid and slower forcing had no effect on percentage of flowering corms or size of spikes. Size of spike did vary regularly in this experiment, however, when all flowers were considered by flowering dates and irrespective of treatment, from three flowers per spike in January to seven in April. No added light was used and light conditions apparently limited the size of the early spikes, irrespective of the treatment used for forcing.

TABLE II—FLOWERING OF ALICE TIPLADY. (CHECKS PLANTED AND TREATMENTS STARTED NOVEMBER 14, 1929)

Treatment	Days, Planting to First Flower	Date of First Flower	Rank, Days to 50 Per cent Germination	Per cent Plants Flowering	Av. No. Flowers per Spike
4 weeks 32 degrees C	92	3/16	1	62	7.70
4 weeks 37 degrees C	96	3/20	2	86	6.67
2 weeks 32 degrees + 5 per cent dip.....	105	3/16	8	57	8.25
2 weeks 37 degrees + 5 per cent dip.....	105	3/16	10	83	7.00
2 weeks 32 degrees C	106	3/16	6	89	7.50
4 weeks 32 degrees C +5 per cent dip..	107	4/1	4	57	6.50
4 weeks 37degrees C + 5 per cent dip..	109	4/3	3	60	5.83
Average first seven	103.0	3/21	4.86	70.6	6.99
4 weeks 20 degrees C +5 per cent dip..	111	4/5	11	83	6.25
4 weeks 5 degrees C	119	4/12	13	58	9.80
4 weeks 5 degrees C +5 per cent dip..	120	4/14	5	100	7.50
4 weeks 20 degrees C	121	4/14	12	100	7.80
2 weeks 37 degrees C	122	4/1	7	100	6.87
Checks............	131	3/25	14	87	7.22
5 per cent dip.......	140	4/3	9	12	7.00
Average last seven	123.4	4/6	10.14	77.1	7.49

The results of an experiment with Alice Tiplady corms are given in Table II. High temperature storage treatments, alone or in combination with a 5 per cent ethylene chlorhydrin dip, are again at the top of the list. In most cases there was no gain from the chemical treatment, and in several instances there was an apparent loss in comparison with the same storage temperature alone.

The Effect of Light on Flowering

The small size of early Arlon flowers has been mentioned as a probable light effect. Both Arlon and Tiplady have, however, flowered under normal daylight at Ames in January and February, indicating photosynthetic rather than photoperiodic effects. Halley has not produced flowers before April 1 without added light, although the use of 1000-watt bulbs has resulted in more and better flowers than 60-watt bulbs, suggesting that something more than light duration is concerned here also.

Chemical Changes in Treated Corms

Sugar analyses of check and treated corms are shown in Table III. The chemical treatments, which did not increase flowering, did not increase the sucrose content of the corms, but the more effective, high-temperature storage resulted in marked increases in the percentages of sucrose. This result is in agreement with unpublished observations on the effect of temperature upon Irish potato tubers.

TABLE III—Sugar Content of Gladiolus Corms. (Check—Recently Dug Corms on November 17, 1929)

Treatment	Alice Tiplady			Le Marechal Foch		
	Germination (Days)	Reducing Sugars (Per cent)	Sucrose (Per cent)	Germination (Days)	Reducing Sugars (Per cent)	Sucrose (Per cent)
Check—none......	65	0.52	1.92	73	0.26	1.40
5 per cent ethylene dip............	69	0.49	1.71	73	0.19	1.14
4 weeks 32 degrees C	24	0.26	2.54	—	0.29	3.33
4 weeks 37 degrees C	38	0.26	2.90	54	0.46	2.55

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Preliminary Report on Breeding Rust Resistant Snapdragons[1]

By Harold E. White, *Massachusetts State College, Amherst, Mass.*

SNAPDRAGON rust was discovered by Blasdale (1) in California in 1896, but it was not until about 1913 that the disease assumed economic importance in the Middle West, and by 1915 had spread to the Eastern Coast. Finally, in 1933 Green (2) at Wisley reports the disease in England for the first time. The disease is of considerable economic importance in greenhouses but more so where snapdragons are grown in the field, and it is of particular concern to seed growers in California.

Breeding work with rust resistant strains of snapdragons was started at the Massachusetts State College Field Station in Waltham in 1930. Dr. E. B. Mains,[2] who had developed strains with a marked degree of rust resistance, distributed seed to California, Arkansas, Virginia, Michigan, and Massachusetts. The Mains' strains had been tested as to rust reaction prior to 1930.

These strains while being very resistant to rust produce irregular shaped flower spikes with magenta colored flowers which are not desirable commercial types. The object then was to take these magenta strains and combine their resistant character with the desirable characters of the commercial types. As far as the writer knows, there has been nothing published concerning these particular resistant strains of snapdragons other than Mains' (3) own comments in a short abstract.

The original resistant strain will be referred to as the magenta strain. This strain was planted in the field with check rows of commercial varieties planted at regular intervals throughout the plots so as to provide thorough inoculation with rust. During the summer, rust was so prevalent on the commercial varieties that artificial inoculation was not necessary except on plants of the magenta strain which showed immunity to rust. In these cases it was merely used to be sure that the plants selected were resistant to rust.

Some 14 plants were selected from the magenta strain for breeding work under glass during the winter. Crosses were made with 10 different commercial varieties, *viz.*, Ceylon Court, White Rock, W. W. Thompson, Afterglow, Helen, Cheviot Maid, Jennie Schneider, Emily, Penn's Orange, and Weld Pink. In addition, approximately 50 commercial varieties were studied for rust reaction in the field and under glass, but in no case were there any plants that showed marked resistance to rust.

In the F_1 generation from the crosses, about 10,000 plants were

[1]Contribution No. 184 of the Massachusetts Agricultural Experiment Station.
[2]Dr. E. B. Mains, Director of the University Herbarium, University of Michigan.

grown in the field, in the F_2 8,000 plants, and in F_3 generation from 3,000 to 4,000 plants.

The magenta strain was not inbred for a pure line before being crossed with the commercial varieties, hence the plants and their progeny were of a very heterozygous nature, making a fine classification of the various phenotypes very difficult.

For instance, what we ordinarily call White (White Rock) is classified by Wheldale (4) as Ivory and carries a factor which inhibits the formation of yellow except for a faint patch of color in the palate of the flower. Thus, a flower may have a white tube, yellow lips or merely a yellow palate; similarly, a condition exists for magenta and the other colors. Reference here to white is used in the sense of ivory, and the term magenta color will include besides true magenta all combinations with red.

The magenta strain when crossed with commercial varieties resulted in a segregation of colors in the ratio of 2 magenta colored to 1 white or yellow colored. Selfed white or yellow flowered plants segregated true for color type in the F_1 and F_2 generations. White (Ivory) was dominant over yellow.

Inheritance of resistance to rust would appear to be a dominant factor. Segregation for resistance in the yellow and ivory flowered plants was 3 resistant to 1 susceptible. The homozygous individuals bred true for color and resistance, whereas heterozygous types segregated again into a 3:1 ratio. Resistance tended to stay with white and yellow colors, indicating a possible linkage between rust resistance and color.

Another point which would tend to strengthen this observation is the fact that when pink, bronze, or red varieties are crossed with the magenta strain the resultant progeny was more susceptible than crosses with white or yellow. Moreover, selections for resistant pink strains have been very difficult. Data on back crosses to determine degree of crossing over are not available at this time.

Commercial varieties when crossed with each other resulted in complete susceptibility to rust. Plants of the resistant parental strain have been carried on for three years with no indications of rust.

Selected resistant strains have withstood direct inoculation tests with rust and have been subjected to field conditions.

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A Preliminary Note on Chromosome Numbers in Iris

By CATHARINE L. BECKER, *University of Minnesota, St. Paul, Minn.*

A STUDY of chromosome numbers in species and varieties of Iris should prove of value in selecting breeding methods for their improvement.

The material studied consisted of four of the Iris species which have been used in breeding garden varieties: *Iris variagata* L., *I. Junonia* Scott and Kotschy, *I. trojana* Kerner, and *I. kashmiriana* Baker; three Pogocyclus hybrids: William Mohr, Ibmacrantha, and Lady Lilford; and eight varieties of tall bearded garden iris; Ophir Gold, Endymion, Schreiner's 39–30, Snow White, Dominion, Grace Sturtevant, Kashmir White, and Argentina. Mr. Robert Schreiner, from whom these iris were obtained, is responsible for their identification. Root tips were collected in the summers of 1931 and 1932, killed in Allen's modification of Bouin's, B 15, sectioned 25 microns thick, and stained with Gentian Violet.

The number of somatic chromosomes found in these iris are shown in Table I.

TABLE I—CHROMOSOME NUMBERS IN SOME IRIS SPECIES AND HYBRIDS

Species	Number 2n	Garden varieties (Complex hybrids)	Number 2n
L. variagata L.	24	Ophir Gold	24
I. Junonia Scott & Kotschy	ca. 48–50	Endymion	24
I. trojana Kerner	56	39–30 (Ophir Gold x Endymion)	24
I. Kashmiriana Baker	56	Snow White	24
Pogo-cyclus hybrids		Dominion	50
William Mohr (Parisians x *I. Gatesii*	22	Grace Sturtevant	ca. 56
Ibmacrantha (*I. iberica* x Amas)	45	Kashmir White	56
Lady Lilford (*I. paradoxa* x *I. pallida*)	46	Argentina	at least 50

Species:—The count of 2n = 24 in *Iris variagata* L. agrees with previous counts for this species (2, 5, 6). The count of 2n = 56 in *I. trojana* Kerner does not agree with Simonet's count of n = 24 in this species (6). The count of 48–50 in *I. Junonia* Scott and Kotschy is approximate because of insufficient material. The count of 2n = 56 in *I. kashmiriana* Baker, a species from India having leathery textured flowers, does not agree with Simonet's statement that this species is an hybrid with 51 chromosomes (7).

Pogo-cyclus hybrids:—The Pogo-cyclus iris are hybrids of the bearded iris (Pogoniris section) by species belonging to the Oncocyclus section. The variety William Mohr, reported to be a hybrid of the variety Parisiana x *I. Gatesii* Foster, has 22 somatic chromosomes and is quite sterile. As Simonet (4, 5) found 20 somatic chromosomes in *I. Loretii* Barbey, *I. sofarana* Foster, and *I. susiana* L. which are separated from each other and from *I. Gatesii* Foster pri-

marily on the basis of flower color, (1), it seems probable that *I. Gatesii* also has 20 somatic chromosomes, and that 10 of the chromosomes of William Mohr were derived from this parent and 12 from Parisiana.

The chromosome number of Ibmacrantha, 45, is somewhat difficult to explain. The parentage is given as *I. iberica* Hoffman x Amas (*I. macrantha* Hort.) Simonet (7) found that *I. iberica* contributed either 10 or 11 chromosomes to some interspecific hybrids he examined. Amas, the other parent, is a nearly sterile clone, and it is possible that this variety may form gametes with a far greater number of chromosomes than are to be expected on the basis of Simonet's count of $2n = 48$ in Amas (6).

Lady Lilford was found to have 46 chromosomes. Its parentage is given as *I. paradoxa* Steven x *I. pallida* Lam. Simonet found that *I. paradoxa* formed gametes with 10 chromosomes (7). *I. pallida* normally has gametes with 12 chromosomes. The 46 chromosomes of the hybrid may represent a doubling of an original complement of 23, of which 10 or 11 were derived from the Oncocyclus parent and 12 or 13 from *I. pallida*.

Garden varieties:—The older garden iris are hybrids of *I. pallida* Lam. x *I. variagata* L. (1). These species both have $n = 12$ and $2n = 24$ chromosomes (2, 3, 5, 6). Longley found that in the meiotic divisions some of the older garden varieties showed 12 bivalents, while many showed from one to several univalents in addition to 12 bivalents. Of the varieties included in this study, the yellow iris Ophir Gold, the blend Endymion, their large flowered yellow seedling Schreiner's 39-30, and Snow White appear to belong among the older type of garden iris on the basis of their chromosome number, $2n = 24$, as well as on the basis of their morphological characteristics.

The newer type of garden iris are complex hybrids involving one or more of such species as *I. trojana* Kerner, *I. Junonia* Scott and Kotschy, *I. kashmiriana* Baker, etc., and they are in general characterized by larger size of plant and flower and by better branching of the flower stalk than is found among the older type. Of the varieties included in this study, Dominion, the Dominion seedling Grace Sturtevant, Kashmir White, and Argentina are included among the newer type of iris. All these varieties were found to have a large number of chromosomes. Dominion, the famous forerunner of the Dominion race of garden iris, has 50 somatic chromosomes. This count agrees with one made simultaneously by Dr. L. F. Randolph and reported to me in correspondence. The variety Grace Sturtevant has approximately 56 chromosomes, Kashmir White 56, and Argentina 50 or more.

Simonet recently suggested (6) that large flowered improved varieties of iris probably have a large number of chromosomes, and that iris breeders should use as parents those varieties which are, as he says, "tetraploid." Among the garden varieties included in this study, the better ones are derived at least in part from species having a large number of chromosomes, and they resemble their high-chromosome progenitors in both number of chromosomes and morphological char-

acteristics. Thus the results here reported tend to confirm the view expressed by Simonet. However, there is at present no evidence that mere doubling of the chromosome complement of the 2n = 24 types would result in improvement, nor that the desirable characteristics of the high-chromosome species are necessarily due entirely to number of chromosomes. It may be possible to retain the desirable characteristics of the high-chromosome species in some of their progeny in spite of reduction in chromosome number.

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Inheritance of Resistance to Rust in Snapdragon

By S. L. Emsweller and H. A. Jones, *University of California, Davis, Calif.*

Abstract

This paper will appear in the University of California Hilgardia series.

Application of Probable Error Concept in Floriculture

By A. M. S. Pridham, *Cornell University, Ithaca, N. Y.*

IN experimental work the investigator often wishes to compare the response by plants grown under treatment A with that by similar plants under treatment B. Conclusions are reached after a consideration of the average difference and of the variability within each treatment. The laws of probability offer a means of estimating the odds that a difference is due to some cause other than chance alone. For a difference of specific magnitude the odds decrease as the variability increases. The complete relationship involves the average difference expressed in per cent, the number of plots in each treatment, the variability of a single plot expressed in per cent of the mean of all plots of the treatment, and a probability integral.

The experimenter may select odds which he believes are sufficiently high to indicate significance, he may set the minimum difference which is economical, and may choose, within limits, the number of plots to be used in each treatment, but he can do relatively little to change the magnitude of variability to suit his purpose.

With these thoughts in mind, a brief study was made of variability in florist crops, particularly the gladiolus. The relationships just mentioned are presented in graph form and may be of assistance in planning experiments or in the interpretations of experimental data in which measure of variability has been omitted.[1]

TABLE I—The Probable Error of a Single Observation (Plant) in Percentage of the Mean (P. E.s % M.)

Plant response	Variety	P. E.s % M.		
		Minimum	Maximum	Mean
Days to bloom from planting	Average	3	21	9.7
	Lucette	1	8	3.6
Number of flower spikes per corm	Average	3	39	13.4
	Lucette	2	20	8.1
Number of florets per spike	Average	3	22	10.4
	Lucette			
Number of corms produced per corm	Average	8	14	10.9
	Lucette	2	10	5.9
Yield by weight, per cent parent corm	Average	16	35	25.2
	Lucette	3	18	9.6

The magnitude of the probable error of a single observation in percentage of the mean value varies with the variety and with the size

[1]The complete report of this work can be found in The Annual Reports of the Department of Floriculture and Horticulture 1926–33; and in a thesis "The General Physiology of the Gladiolus," by A. M. S. Pridham. These are unpublished.

of corm. Alice Tiplady, Cameo, and Sheila are usually above the mean while the variety Lucette is consistently below the mean value. The size of corm also plays a part, though corms of moderate size produce plants lower in variability than do large or small corms.

According to the theory of variability (P. E. m) is reduced inversely as the square root of the number of plants in the plot. In the present studies this relationship was found to be only approximate, the observed value being higher than the theoretical.

In comparison with other greenhouse crops, the variability in gladiolus does not appear excessive. Stem length of chrysanthemums average value of 9 per cent. In size of flower the corresponding values were 1 to 8 per cent, averaging 6 per cent, and for date of bloom was found to vary (P. E.$_s$ % M.) from 1 to 21 per cent with an average value of 1 per cent when the date is measured from planting and 20 per cent when measured from date of the first bloom.

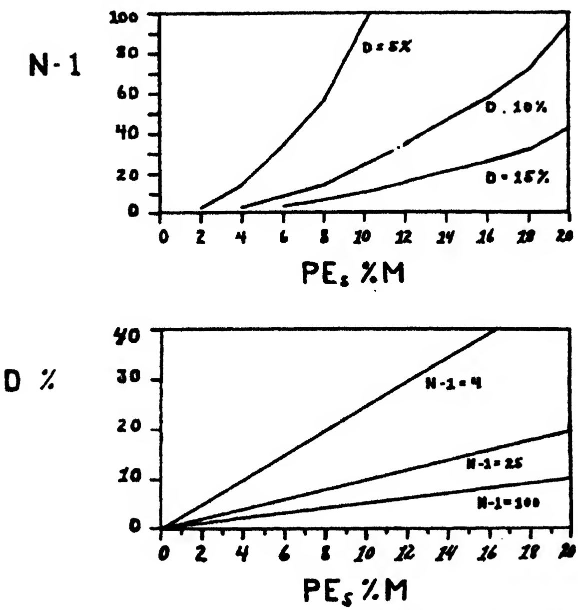

FIG. 1.—The relation of the difference (D) between treatments A and B expressed in per cent, variability (P. E.s % M.) and the number of observations (N)-1 necessary for odds of 99:1 against the difference being due to chance alone.

Similar characters in carnations, as reported by Weinard and Decker (2), when interpolated, gave similar values. In this respect florist crops are somewhat more variable than small grains and less variable than live-stock (1).

Using an average figure of 10 per cent for the value of P. E.$_s$ % M. and a minimum difference of 10 per cent to make a new treatment economical, it is evident in Fig. 1 that about 20 plots per treatment would be required to demonstrate such a difference satisfactorily (odds 99:1).

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Moisture in Relation to the Rooting of Cuttings

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MANY investigations have been made of factors affecting the rooting of cuttings, but seldom has moisture been mentioned. Often commercial plant propagators have said that it makes little difference if a coarse or fine sand is used as a rooting media, but after the operator has learned how to handle a particular grade of sand, he should not make a change. Thus, they are indicating that learning how to water the propagating bed is an important factor governing success.

In an attempt to obtain some data upon the importance of moisture in the rooting of cuttings, some equipment was set up whereby effects of the moisture content of the sand could be studied. The equipment consisted of pans in which was placed the propagating media. A water table was established in the media and held at a constant level by means of two lines taken from a sealed reservoir located above the propagating bed. The height of the media above the water table determined the amount of moisture it contained.

In these studies, a clean sharp river sand of medium grade with a pH of about 8.5 was used as a rooting media. The sand was passed through a screen to remove the coarser pebbles.

The care of the cuttings differed from the common commercial treatment only in that they were never watered from above.

Table I shows the moisture content of the sand of the plots and the percentage of cuttings which rooted. Preliminary studies showed that for some of the varieties the two plots with the least moisture were too dry to induce rooting, therefore, these plots were not used in all tests. The media in the plot of highest moisture content was so wet that water would rise to the surface if the sand was tamped. The range in moisture content in a given plot was caused mainly by the difference in firmness of the sand in different tests.

Santoliana and snapdragon are the only varieties which failed to give the greatest percentage of rooting in the plots of highest moisture content. Some of these tested are generally thought to root best in a comparatively dry media, as for example, geranium, but here they have responded best to high moisture. Coleus and sedum are the only ones which gave a satisfactory commercial precentage of rooting over a wide moisture range. Sedum rooted in all of the plots but the percentage was reduced in the plot of least moisture. In this plot the cuttings wilted and remained in that condition until after roots had formed. The number of roots formed in this case were few as compared to those of the other plots.

It was observed during these studies that cuttings propagated in sand containing from 7.5 to 17 per cent moisture were the only ones which decayed in a way typical of those in the commercial propagating beds. Those in the more moist media which failed to root usually showed decay at the base while the tissue immediately above

appeared healthy. The cuttings in the drier media which failed to root dried up instead of decaying, apparently due to the lack of moisture. It was also observed that in most cases callus formation was light in the very moist media.

TABLE I—MOISTURE CONTENT OF SAND IN RELATION TO ROOTING OF CUTTINGS

Material	Moisture as Percentage of Dry Weight of Sand					
	19–21	15–17	9–11	6–7,5	3–4	1
Percentage Rooting						
Carnation 1st trial						
Pink Abundance	100	96	22	00	—	—
Spectrum	100	98	56	18	—	—
Centaurea sp.	93	87	7	00	00	00
Coleus						
Chicago Bedder	100	100	90	100	00	00
Gold Bound	100	100	100	33	00	00
John Pfitzer	100	100	100	90	—	—
Verchaffeti	100	100	90	100	100	00
Achyranthus McNally	100	80	13	00	00	00
Geranium						
General Grant	100	73	47	47	27	00
Skeleton Leaved	100	100	60	27	00	00
Lantana						
Harkett's Perfection	33	13	00	00	00	00
Iolonda	73	7	00	00	00	00
Melissifolia	33	20	00	00	00	00
Santoliance						
Chamaecyparrus	45	50	75	80	20	00
Sedum						
Sarmentosum Varig	100	93	100	93	93	60
Sarmentosum	95	95	100	100	100	85
Snapdragon	70	75	20	00	00	00
Chrysanthemum						
Brownie	100	85	20	00	—	—
Garnet	65	20	8	00	—	—
Gold Lode	95	45	35	00	—	—
Honey Dew	90	80	2	00	—	—
Nerssia	100	35	00	00	—	—
Sunburst	98	100	55	2	—	—
Yellow Turner	95	30	10	00	—	—

These studies indicate that lack of moisture in the sand reduced materially the percentage of rooting and therefore that the moisture and air ratio in the rooting media is an important factor governing success in the rooting of cuttings.

Influence of Media and Maturity of Wood on the Vegetative Propagation of *Camellia japonica*

By F. S. Batson, *Ohio State University, Columbus, O.*

THOUGH the stem cuttings of many species of plants have shown marked differential response to various types of rooting media and in many cases the time of taking cuttings from the parent plant has shown a definite relation to successful rooting, very little work has been done with *Camellia japonica* L., a valuable ornamental of the South. Hume (3) without presenting data states that a mixture of sand with peat or woods mold is the best medium for propagating Camellia and that cuttings taken from the plant from July to November will root satisfactorily. Zimmerman and Hitchcock (5), Chadwick (1), and Gardner (2) have shown that a distinct seasonal variation exists in the rooting of many plants. To determine the influence of certain media and of the maturity of the wood on root and shoot development of stem cuttings of *Camellia japonica*, the following experiment was undertaken.

The media used were river sand (pH 7.4 to 8.2), a mixture of equal parts of sand and German peat (pH 5.2 to 5.6), and German peat (pH 4.6 to 5.2). A Wardian case was filled to a depth of 5 inches. Three lots of cuttings taken from a single plant were used. The first lot remained in the case from August 16 to October 12, the second from December 17 to March 13, and the third from February 9 to May 4. Each lot of cuttings was taken from the plant a few days before they were placed in the case. In this way the influence of wood maturity was determined. The cuttings consisting of 3 to 4 inches of tips of the current season's growth were cut ¼ inch below the fourth or fifth node from the tip.

From August to October soil temperatures varied greatly. During clear days maximum temperatures of 90 to 95 degrees F were frequently attained. However, from October to May a more favorable temperature range (83 to 87 degrees F) was secured through the application of heat supplied by an electric cable. Since only one thermostat was used to control the temperature in all three media, the temperature of the sand was unavoidably 1 to 2 degrees F lower than that of the peat and sand-peat mixture.

Air temperatures fluctuated between 70 and 76 degrees F except during August and September when they were considerably higher. The pH of the water used was 7.2.

The data presented in Table I show that in all cases sand and the sand-peat mixture produced a greater percentage of rooted cuttings

[1]These data were obtained and prepared for publication at the Mississippi Station during 1932 and 1933 when the writer was a member of the Agricultural Experiment Station staff.

[2]The writer expresses his appreciation to Dr. J. B. Edmond for assistance in planning the work and in the preparation of the manuscript, and to Professor R. V. Lott for advice and assistance throughout the course of the investigation.

TABLE I—THE INFLUENCE OF ROOTING MEDIA ON THE GROWTH OF *Camellia japonica* CUTTINGS TAKEN AT VARIOUS SEASONS OF THE YEAR. AUGUST 16 TO MAY 4. 1932–33[1]

Cutting Development	Media			Differences		
	Sand	Sand[2]-Peat	Peat	Sand minus Peat	Sand-Peat Minus Peat	Sand-Peat Minus Sand
August 16 to October 12 (57 days)						
Per cent cuttings producing roots	85	95	60	25	35	10
Per cent cuttings producing shoots	0	0	0	0	0	0
December 17 to March 13 (86 days)						
Number roots per cutting	7.4±1.11	11.6±1.45	6.0±1.09	1.4±1.55†	5.6±1.81*	4.2±1.83†
Total length roots per cutting (inches)	14.1±1.39	21.1±2.60	6.0±1.23	8.1±1.85*	15.1±2.88*	7.0±2.95†
Per cent cuttings producing roots	90	75	55	35	20	—15
Per cent cuttings producing shoots	25	95	60	—35	35	70
February 9 to May 4 (84 days)						
Number roots per cutting	7.8±1.12	13.6±1.25	1.9±0.70	5.9±1.31*	11.7±1.43*	5.8±1.68*
Total length roots per cutting (inches)	8.8±1.16	23.0±2.32	2.8±1.07	6.0±1.58*	20.2±2.50*	14.2±2.59*
Per cent cuttings producing roots	75	85	20	55	65	10
Per cent cuttings producing shoots	80	100	100	—20	0	20

[1]20 cuttings used as a unit in all media.
[2]Equal proportions.
*Differences are considered significant.
†Differences are considered insignificant.

than peat. Differences between the sand and the sand-peat mixture are narrow and inconsistent. Sand produced the greater percentage of rooted cuttings from December 17 to March 13, while the sand-peat mixture produced the greater percentage from August 16 to October 12 and from February 9 to May 4. The sand and sand-peat mixture also produced a greater total length of roots per cutting than the peat. The differences between the sand and the sand-peat mixture, though insignificant in two cases out of four, show a decided tendency for the sand-peat mixture to produce a greater number of roots and a greater total length of roots than the sand. Apparently, mixtures of sand and peat are more satisfactory than sand or peat for the propagation of stem cuttings of *Camellia japonica*.

A distinct relation exists between the number of roots and the total length of roots per cutting. In all cases shoots which produced a large number of roots correspondingly produced a greater total length.

However, since long roots are more likely to be destroyed in transplanting than short roots, the production of a large number of short roots rather than a small number of long roots would seem to be more desirable.

The percentage of cuttings producing shoots varied with the medium. In all cases shoot production was less evident in sand than in the sand-peat mixture and in peat. Since the nitrogen supply in peat is greater than in sand, the differences in shoot growth may have been due to the differences in nitrogen content of the two media. Reid (4) has shown that tomato cuttings high in carbohydrates produce abundant shoot growth in nutrient solution containing nitrate, while cuttings high in carbohydrates produce no shoot growth in nutrient solution containing no nitrate. Since the cuttings of the *Camellia japonica* used in this experiment doubtless contained relatively large quantities of carbohydrates, their response to nitrogen would seem somewhat similar to that secured by Reid with tomato cuttings.

The seasonal differences in root development are small, inconsistent, and in all cases insignificant. In the peat alone, the period from December 17 to March 13 produced a greater number of roots per cutting than the period from February 9 to May 4, while in both sand and peat the former period produced a greater total length of roots per cutting than the latter. In the sand-peat mixture root development was somewhat greater for the period February 9 to May 4 than for the period December 17 to March 13. Evidently cuttings taken from December to February will root satisfactorily.

Marked differences in shoot production between the two periods are evident. In all cases cuttings grown from February 9 to May 4 produced a greater percentage of shoots than those grown from December 17 to March 13. Undoubtedly the cuttings for the period from February 9 to May 4 were subjected to a longer period of freezing temperatures than those taken for the period December 17 to March 13. Zimmerman and Hitchcock (5) have shown that low temperatures are necessary for the production of shoots in stem

cuttings of holly. Stem cuttings of *Camellia japonica* are undoubtedly similarly influenced.

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New Lilies for American Gardens

By David Griffiths, *U. S. Department of Agriculture, Washington, D. C.*

Abstract

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Propagation of Evergreens Under Different Temperatures at Different Times of the Year

By G. B. Durham, *Rhode Island State College, Kingston, R. I.*

THE test here reported was started in the fall of 1932 at the request of several of the larger nurserymen in the state, with 10 common needle-bearing evergreens,[1] two species of Euonymus, one Ilex, one Rhododendron, and one Laurel as the basis of work. Later in the experiment an Azalea and a Heather were added.

Cuttings were taken on the current year's growth on stock furnished by the nurserymen on the mainland of the state. In view of the fact that there is always more or less controversy as to the particular type of cut to take, the stock was divided into three approximately equal piles and straight, heel, and mallet cuttings were taken from each species at the time of placing in the propagating beds. The main bulk of the first run of stock was placed in the beds during the last 10 days of November.

Subsequent microscopical examinations of free-hand sections for starch content were made as soon as possible to determine whether there might not be a correlation between the amount of starch present in a cutting and the rate of rooting. A standard iodine-potassium iodide solution was used.

To minimize errors due to heat losses, all sections of the benches were insulated on the bottom with from 1 to 1½ inches of magnesium wool, water bound and covered with a coat of shellac followed by a coating of waterproof varnish. This substance had enough natural cracks due to drying to provide drainage for any excess water that might be added to the benches. As a further drainage precaution, from 1 to 1½ inches of slag cinders were used above this insulation. The slag also acted as an aerating medium. On top of these base materials propagating media of coarse sand, sand and granulated peat moss and peat moss and soft coal cinders were spread to a depth averaging about 4 inches. The latter two media were mixed in proportions varying from 1/3 to 2/3 peat moss and the remainder sand or cinders. Sand was used at the special request of the growers who seldom used any other medium.

Overhead heat was provided by electric coils placed 18 inches above the cutting bed. Subterranean heat was provided by lead-insulated cables placed from 3 to 4 inches below the top surface of the propagating media. All heated sections were thermostatically controlled and metered.

The following tabulation shows the average temperatures at which

[1]This work was carried on under the direction of Dean G. E. Adams of the School of Agriculture and Home Economics to whom I am indebted for valuable criticism and advice. Much of the apparatus used was loaned by the Rural Electrification Committee of the New England Light and Power Company.

the various sections were maintained as well as the possible effect of different media on resulting temperatures where two sections of a bed were operated on the same coil. This effect is illustrated in sections 2, 4, and 6 with subdivisions A and B.

Section	Source of heat	Average Temperature of Medium (Degrees F)	Rooting Medium
1	House 56°F	56	Sand
2A	Overhead coil	64	⅓ peat, ⅔ cinders
2B	Overhead coil	60	Sand
3	House	58	½ peat, ½ sand
4A	Sunken cable	80	½ peat, ½ cinders
4B	Sunken cable	71	3 ins. sand, 1 in. peat
5	House	61	½ peat, ½ cinders
6A	Sunken cable	71	½ sand, ½ peat
6A	Sunken cable	76	Sand

Sections 4A and B were on the same meter and coil and 6A and 6B were on another. The differences in temperatures, therefore, reflect the effect of media on bed temperatures.

Representative samples of data are taken for illustration although the results vary somewhat if all varieties and species were used.

TABLE I—ROOTING OF TAXUS CUTTINGS (1932–1933) UNDER VARIOUS CONDITIONS OF TEMPERATURE AND MEDIA

Bench	Number of Days to			Number Died	Number Rooted	Per cent Rooted
	First Callus	First Rooting	Last Rooting			
			T. cuspidata (*Struck Nov. 22*)			
1	43	193	225	6	33	84.6
2A	48	193	225	13	26	66.7
2B	43	193	225	14	25	64.1
3	43	105	225	3	38	92.6
4A	43	55	211	0	40	100.0
4B	43	69	128	1	31	96.8
5	69	118	285	8	31	79.5
6A	48	118	—	4	9	69.2*
6B	48	67	—	27	12	30.8*
			T. cuspidata nana (*Struck Nov. 30*)			
1	35	69	217	5	41	89.1
2A	35	97	217	9	34	79.0
2B	35	61	217	11	38	77.6
3	40	82	217	3	43	93.4
4A	35	61	67	0	43	100.0
4B	35	61	165	13	36	73.5
5	35	100	165	24	14	36.8
6A	47	61	138	0	36	100.0
6B	47	61	165	7	36	83.7

*Shifted to flats April 3.

Table I presents the behavior of two forms of Taxus in the various sections. It is interesting to note that the variety *Taxus cuspidata*

nana is usually considered hard to propagate. In this case it gives better results in heated beds than the parent form. It also rooted in the majority of cuttings in much shorter time than did *T. cuspidata.* Subsequent batches of cuttings taken by students as late as April 1, 1933, gave similar results, but in less time.

Table II presents results with one of the Thujas that is usually difficult to propagate, as well as with one of the hardest of the Junipers under normal propagating conditions. Both of these forms are usually susceptible to propagating bed diseases which account for most of the mortality. No appreciable seasonal difference was observed in Thujas, but Junipers taken from mid-February to mid-March were well rooted 10 to 12 weeks later in the heated beds other than sand.

TABLE II—Rooting of Thuja and Juniperus Cuttings (1932–33) Under Various Conditions of Temperature and Media

Bench	Number of Days to			Number Died	Number Rooted	Per cent Rooted
	First Callus	First Rooting	Last Rooting			
			T. occidentalis lutea (*Struck Nov. 23*)			
1	61	251	251	57	7	10.9
2A	140	251	251	57	2	3.4
2B	54	251	251	60	10	14.3
3	47	154	251	33	11	25.0
4A	42	54	236	45	15	25.0
4B	42	236	236	44	9	17.0
5	47	—	—	42	—	—*
6A	54	131	236	46	2	4.2
6B	47	236	236	67	2	2.9
			J. Chinensis Sargenti (*Struck Nov. 22*)			
1	119	252	252	30	35	53.8
2A	178	252	252	33	41	55.4
2B	178	252	252	60	14	18.9
3	178	252	252	53	17	24.3
4A	48	118	237	24	30	55.5
4B	62	237	237	35	33	48.5
5	—	237	237	27	1	3.6
6A	—	132	—	14	2	12.5*
6B	69	237	237	48	10	17.3

*Shifted to flats April 3.

Table III shows some of the broad-leaved evergreens that might be of commercial importance in some parts of the country. *Euonymus latifolius* taken in the fall roots well under most conditions if given time enough. When, however, this species is cut in the early spring the response is rapid at high temperatures, with the growth continuing throughout the growing season, while plants from fall or winter cuttings usually remain dormant during the following growing season. Similar rooting responses were obtained with *Ilex opaca* but the subsequent growths in this case seemed to be equal. The chief

gain from spring cuttings then, would be a shorter period in the bench with less labor and heat outlay. The main disadvantage to spring propagation is that it interferes materially with other duties of commercial growers.

TABLE III—Effects of Temperatures, Media, and Season on Rooting of Cuttings of Broadleaf Evergreens (1932–1933)

Bench	Date Struck	Number Days to First Rooting	Number Days to Last Rooting	Per cent Rooted
		Euonymus latifolius		
1	Nov. 18	31	120	89
4A	Nov. 18	27	28	100
1	March 15	14	167	100
4A	March 15	14	127	100
		Euonymus alatus		
1	Nov. 18	78	190	100
4A	Nov. 18	78	138	100
1	Mar. 12	34	77	100
4A	Mar. 12	18	23	100
		Ilex opaca		
3	Dec. 8	129	165	89
4A	Dec. 8	41	66	100
3	Mar. 10	51	86	100
4A	Mar. 10	22	36	100
		Rhododendron maximum		
3 and 4A	Nov. 22	—	—	—*
		Kalmia latifolia		
4A	Nov. 22	44	87	100

*Callus in 130 days, no rooting.

Azalea mollis cuttings taken on October 28, 1933, were rooted 4 weeks later at a temperature of 80 degrees F in peat moss and cinders, while those in other media at the same or lower temperatures had shown no signs of rooting on December 26. Scotch heather cuttings taken on October 28, 1933, were rooted and flatted on December 9, from the peat and cinder section. Cuttings in two other sections were not callused on December 26. These cuttings showed a high starch content when free-hand sections, turning almost black, were treated with iodine-potassium iodide solutions. This treatment is to be used as a check on all evergreen cuttings struck this winter. Conifers that showed a high starch content in late October were callused in the heated sections on December 26, when but few in the control sections showed callus. Those showing traces of low starch content have shown no signs of callusing in any section.

From the above data it would seem that there is a correlation between the amount of starch present and the rate callusing and also of rooting at controlled temperatures. Seasonal fluctuations will occur

in optimum conditions for most evergreens used in propagating by means of cuttings.

Short periods of high temperatures in a well-aerated moisture-retaining medium will, if the cuttings are kept free from disease, give better results than longer periods at lower temperatures.

No appreciable differences could be seen arising from use of any particular type of cut in this test.

Top or overhead heat is not beneficial in rooting evergreens.

Electric heated beds (bottom heat) appreciably hasten rooting in Taxus, Ilex, and Euonymus and seem to be commercially economical the cost per square foot of bench surface averaged less than 1 cent per month with power at 3 cents per kilowatt-hour.

Color Changes in the Hydrangea

Bv G. H. Poesch, *Ohio State University, Columbus, Ohio*

Abstract

This material will be published in bulletin form by Ohio State University.

Some Effects of Storage of Flowers in Various Gases at Low Temperatures on Their Keeping Qualities[1]

By L. E. LONGLEY, *University Farm, St. Paul, Minn.*

VARIOUS chemical treatments have been suggested for prolonging the life of cut flowers, but Hitchcock and Zimmerman (1) report that no marked benefit was found in the use of 50 different chemicals. Thornton (2) reports that the use of CO_2 in the storage atmosphere retarded the opening of roses, at temperatures of 38 and 50 degrees F. Rates of CO_2 used varied from 5 to 30 per cent, but 7 days was the limit of effective storage.

The experiments here reported indicate the results of storage at 33 to 34 degrees F. A large automatically controlled refrigerating chamber was used; the flowers were kept with their stems in water and placed in garbage cans with tight fitting covers and sealed still further around the edges with Scotch tape.

In a preliminary series, CO_2 was used at the rate of 8 and 10 per cent of the atmosphere; it was introduced into the cans through a meter from a drum of compressed CO_2 gas. A check lot was placed in the open refrigerator and one in natural atmosphere in a sealed can. Also one was wrapped in paraffined paper. Briarcliff and Talisman roses and Matchless carnations were used. Flowers were taken out from each lot at weekly intervals and placed under living room conditions to ascertain how long they would keep. Fresh cut flowers from a greenhouse were used each week as a check. The results with Briarcliff roses indicated that CO_2 retarded the opening somewhat, the 10 per cent more than the 8 per cent, and it also gave the flowers a brighter color. However, in general the flowers in the open lot kept as well or better than those in the CO_2, except for the fourth week. The flowers were also somewhat softer in the CO_2 lots. The flowers in natural atmosphere in the can and those wrapped in paper were poorer than the CO_2 lots in keeping by 1 to 2 days. None of the flowers were of much value after being stored for 4 weeks; those stored 3 weeks had value only for funeral work, but up to the end of the second week the open lot kept nearly as long as the unstored group though there was some drying of the outside petals.

With Talisman roses for the first 2 weeks the unstored lots kept 1 to 2 days longer than the next best lot, those in 10 per cent CO_2. Flowers of this latter series, however, were faded and a dingy purplish color on the backs of the petals; also the stems were greatly weakened. After the second week none of the Talisman flowers had any value.

With Matchless carnations, however those in the CO_2 chambers kept best of all the stored lots, the 10 per cent CO_2 group being best. This effect was most marked at the end of the second week when the CO_2 lots kept as well as those which were unstored. In general, 1 to

[1]The author wishes to acknowledge the cooperation of Dr. R. B. Harvey in making suggestions as to methods and equipment, and of Mr. L. Sando in assisting in making notes on the stored flower.

2 days were added to the life of the flowers in the CO_2 chambers as compared to those stored in the open. These showed effects of drying from the circulation of air about them. By the third week the CO_2 lots kept for a period of about 2 days less than the unstored flowers. They showed, moreover, a deformity of the flowers, in that the center petals elongated considerably and the outer ones tended to reflex, making a flower longer vertically than normal.

Further tests were made, employing some other gases, such as SO_2 and H_2S and CO_2 at the rate of 25 per cent. SO_2 used at the rate of 1 part to 50,000, and 1 part to 200,000, produced spotting of the petals which later caused drying or rotting. When used at the rate of 1 part to 2,000,000, very little spotting took place and the keeping of the carnations was greatly improved, but with roses the results were poor.

H_2S gave still better results with carnations but not with roses. With Matchless carnations, the flowers were nearly as good at the end of the second week and the third week tests as were the unstored flowers. With Spectrum carnations, the flowers in H_2S were better for these periods than were the unstored ones; showing this had considerable value in prolonging the keeping of carnations. One gram of K_2S was oxidized in 10 cc of H_2SO_4 in the bottom of the 20-gallon can.

In general, the H_2S lot was considerably better than those in 10 per cent CO_2, and 25 per cent CO_2 showed uniformly poor results.

In the first series of tests, it was observed that the flowers in the CO_2 chambers eventually became somewhat soft and flabby, and the stems rather weak. So a few flowers were stored in 10 per cent CO_2 with their stems in a 10 per cent sucrose solution. These flowers remained stiffer than those in pure water but the petals of the roses became rugosed or blistered. Carnation flowers in sucrose solution turned brown sooner and kept a shorter time than those in water.

To obviate the drying effect of air circulation on the flowers stored in the open refrigerator, one lot was kept in a carton whose top was covered with cheese cloth. Briarcliff roses stored thus kept better than under any other conditions though not quite so long as the unstored lots. Carnations also kept better than those in the open.

Summary

Storage of cut flowers at 32 and 33 degrees F in containers charged with gases showed differing results with different kinds and varieties of flowers.

After removal from storage Briarcliff roses lasted longest when kept in ordinary atmosphere, if protected from air circulation; however, the 8 and 10 per cent CO_2 atmosphere kept the flowers from opening as rapidly during the course of the storage period; 25 per cent CO_2 not giving good results. SO_2 in dilution stronger than 1 to 2,000,000 caused injury to the petals, though it retarded opening. H_2S retarded opening but did not increase keeping qualities. Roses with their stems in 10 per cent sucrose solution in 10 per cent CO_2 atmosphere were retarded in opening, but the petals became rugosed and deformed.

Talisman roses did not keep well under any of the treatments. CO_2 treatment caused a fading of the red color often to a yellow, and sometimes a dingy purple appeared with this treatment.

With carnations, the H_2S treatment caused the flowers to keep as well, or better, than the unstored lots at the end of the 2, and also the 3 week period. SO_2 at a dilution of 1 to 2,000,000 was nearly as good, there being only slight spotting at this dilution; those protected from drying in a carton were nearly as good. Ten per cent CO_2 increased the life of the flowers from 1 to 2 days.

Carnations with their stems in 10 per cent sucrose solution in 10 per cent CO_2 atmosphere did not keep as long as those in water.

In general, 2 weeks storage seemed about as long as would be worth while, though carnations in the H_2S lots kept well through the 3 week period.

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Trends and Results in Horticultural Extension

By C. P. Close, *U. S. Department of Agriculture, Washington, D. C.*

IN keeping with national and world conditions which are bringing about changes in all walks of life, there will be changes in the trends of effective horticultural extension work. The old order of things is passing and we must now adjust our efforts to meet the new problems as they appear. One trend which is developing fast is the "live-at-home" movement which places on horticulture the heavy burden of teaching hundreds of thousands of people to grow their own food. The State horticultural specialists and county extension workers are assisting State relief forces in growing 100,000 relief gardens in Alabama, 315,000 in Pennsylvania, 135,000 in Kentucky, 130,000 in Oklahoma and 92,000 in Arkansas, besides sponsoring a greatly increased number of the regular farm and home gardens in these States. Most of the other State specialists are also carrying a heavy load of the same kind of garden work.

In November, 1933, the cotton belt States organized a comprehensive project to plant gardens and home orchards on cotton farms insofar as this is practical.

In commercial fruit and vegetable work the trend will not be so much toward larger crops as toward ensuring that a larger portion be of the better grades and that it be grown, washed, graded and packed at reduced expense per unit. There will undoubtedly be increased cooperative packing and marketing among the growers who do not have great enough volume of output to carry the expense of modern equipment and marketing individually.

Horticultural extension was moving along normally until heavy cuts in appropriations in some States caused a slight reduction of the extension forces, and then the administration of the Agricultural Adjustment Act took over temporarily a part or all of the horticultural specialists in the cotton and grain States.

State Allotments and Specialists:—For the present fiscal year, 1933–34, 44 States with horticultural projects have allotted $352,-348.17, a drop of $61,541.23 from last fiscal year, 1932–33. The horticultural allotment is exceeded by only two other lines of work, namely, dairying by $19,697.96 and agronomy by $3,967.28. There is, however, a considerable sum used by home agents and county agents in horticultural work for which we have no separate accounting.

The number of State horticultural specialists was 105 at the beginning of this fiscal year, a drop of three from last year.

Result Demonstrations Completed in 1932:—In completed result demonstrations in 1932, horticulture leads all lines of extension work. In the adult work there were 262,296 and in the boys and girls work there were 178,943 making a grand total of 441,239 horticultural result demonstrations completed in 1932. In the boys and girls work

there were 112,571 gardens, 43,651 landscape plantings, 17,774 demonstrations with potatoes, 2,263 with grapes, 5,373 with tree fruits, and 5,468 with small fruits.

Landscape Work:—Another horticultural trend which rivals garden work in popularity is that of beautifying home surroundings. This touches all grades of homes from the humblest shanty to the big farmstead. There are many times more calls for help in landscaping than the State and county people can take care of. The extension forces are cooperating closely with State federations of garden clubs, with hundreds of county or local garden clubs, and with thousands of individuals. In 1932 there were 45,651 landscape demonstations completed by the club boys and girls, and 57,916 completed by adults. This makes a total of 101,567 demonstration places to teach people how to improve home and community surroundings. No record is available of the many thousands of homes improved as a result of these demonstrations.

In Iowa alone last year 478 extension schools to train local leaders were held. Besides these schools there were 896 landscape meetings and in all 18,208 people were helped in home improvement work. This resulted in 6,273 home grounds, 1,202 complete farmsteads, and 79 civic projects and State parks being beautified.

In Michigan, Prof. Gregg held 69 lecture demonstrations this year with a total attendance of 6,867 people. From November 1932 to April 1933 he held lesson schools in 55 counties. At another series of lesson-meetings, 3,388 people were in attendance.

In Coahoma County, Mississippi, with a white population of 3,000, the home agent, Miss Eudie Kavanaugh was instrumental in having more than 1,000 rose bushes planted last spring.

In Ohio this year there was held a series of 18 flower-show schools sponsored by the Ohio Association of Garden Clubs composed of 146 clubs with 6,000 members. Training was given in the planning, management and judging of flower shows.

Since Ohio was allotted 15½ million dollars of N. R. A. funds for highway work, a State Council for Roadside Improvement reaching about 185,000 members of garden clubs, federated women's clubs and P. T. A. associations, has been organized, and has requested from the Government $500,000 of the N. R. A. funds for highway beautification. This has been done under the leadership of Mr. Victor H. Ries, extension floriculturist.

Miss Ruth Fairbairn of Sebastian County, Arkansas, selected four communities of about 50 families each for community landscape improvement. She appointed a committee of three women from each community to visit and interest every family in home improvement work. All were in favor and the project was started. The grounds around the homes were cleaned up, flowers and shrubs were planted, the roadsides and school and church grounds were also put into good condition, and every home in each community shows evidence of sincere work in beautifying the surroundings. These communities are north of Ft. Smith, scattered along the road from 8 to 18 miles out of Ft. Smith. It was not necessary to buy any shrubs because

people in Ft. Smith who were taking out crowded shrubs donated them to these communities.

Orchard spray rings:—The most successful and satisfactory way to take care of farm or semi-commercial apple orchards is through the use of orchard spray rings. Wisconsin leads in this work with 219 spray rings having more than 2,000 members. Eighty-five per cent of these spray rings are cooperative in that the members of each ring own the spraying outfit and employ a man to spray all of the orchards. This method is entirely satisfactory if the spray operator follows the teaching of the State specialist. Last year 38 extension schools were held for the explicit purpose of teaching spray operators how to take care of the spray outfit and to do the spraying properly. It was considered unnecessary to give the orchard owners this training so long as the spray operators had it.

In a few spray rings one man owned the spray outfit and did all of the spraying. As a rule this arrangement did not prove very satisfactory.

In 1932 about 45 orchard spray rings were operating in Indiana. Figures showed that the cost of spraying with a cooperatively-owned spray rig was approximately 60 cents per average sized tree for the season. The result is that many farm orchard owners join spray rings, attend meetings and give their trees good care in spraying, fertilizing and pruning.

Apple maggot control:—This is one of the outstanding lines of work carried on in the New England States. Application of two special poison sprays about July 6 and July 20 to 25, picking up and destroying dropped apples after July 15, and taking out seedling and other uncared for apple trees within 300 yards of the orchard to be protected, has given control. Many hundreds of useless apple trees were taken out in a clean-up campaign this year.

Ninety per cent clean apple club:—This is another important interstate project in New England. Prof. E. P. Christopher of Rhode Island and Prof. C. O. Rawlings of New Hampshire will discuss this project at this meeting.

Vegetable work:—Mr. C. H. Nissley of New Jersey gives figures on the results of the use of plant-house grown plants, in comparison with plants not grown in plant houses. On 72,344 acres plant-house grown plants produced crops valued at $10,334,784.00. Plants not grown in plant houses set on 72,638 acres produced crops worth $8,941,250.00.

In Michigan in 1932, Mr. Mahoney had about 1,000 commercial gardeners following his recommendations as to seed strains, varieties, soil improvement and pest control. About 30,000 home and roadside market gardeners followed his recommendations on varieties, strains and sources of seed and general care of crop. There were more than 200 growers who followed directions in the growing of celery, rhubarb, chicory, onions, melons and cabbage. Nearly 600 growers followed his instructions in the production of carrots, spinach and early cabbage on muck soil. In the growing of canning crops under

contract about 150 more followed the best practices recommended by Mr. Mahoney.

In 1932 there were 80 members of the 600 bushel per acre potato club in Colorado who qualified by growing this amount per acre. About three-fourths of the growers used certified seed and the others used a high grade of uncertified seed. In 254 demonstrations in 14 counties, certified seed produced 60 bushels per acre more than did uncertified seed. Had certified seed been used in planting all of Colorado's 100,000 acre potato crop, the yield would have been approximately 6,000,000 bushels more than it was.

In Connecticut during the past 6 years, Prof. Wilkinson has been able to have 3,000 acres of tobacco land used for potato growing. Aside from this new potato area, he also has another new area of 10,000 acres which had never been planted to potatoes before. The average yield of this new project is 167 bushels per acre, but some of the best growers obtained a yield of 300 bushels per acre.

Greenhouse work:—One thousand tons of clover chaff which was formerly a waste product on farms, were used as a mulch on 160 acres of greenhouse tomatoes and cucumbers in Cuyahoga County, Ohio, and saved the greenhouse operators about $60,000 because chaff was nearly $400 an acre cheaper than manure. Before the greenhouse vegetable specialist, A. W. Marion, demonstrated this use for clover chaff, it was usually burned to get rid of it. Clover chaff gives even better results than manure for tomato and cucumber greenhouse growing.

Three hundred thousand dollars was the profit reaped by greenhouse men around Cincinnati and Toledo, Ohio, by following the extension service advice in growing tomatoes and cucumbers instead of lettuce as a fall crop. This increased income came from 60 acres of greenhouse space.

Twilight Meetings:—Several years ago Prof. Wilkinson started twilight meetings which vegetable growers attended after supper. This gave them a couple of hours to visit and examine vegetable crops at the places where the meetings were held. Similar meetings are held by Mr. Rollins in carrying on his fruit work. The truck and fruit men seem to think they can take time for meetings better in the evening than they can during the day.

Final:—These are a few of the interesting results obtained in horticultural extension in different parts of the United States. Many more might be cited but time forbids. While we are reaching many thousands of people throughout the country, the Washington Office believes that we ought to be reaching thousands more. It is the little fellows with limited resources or opportunities who need our most serious consideration.

Four Years of the Spray Service and 90% Clean Apple Club in Rhode Island

By E. P. Christopher, *R. I. State College, Kingston, R. I.*

IN the fall of 1929 orchard run samples of Baldwin apples were collected from the orchards of eight large growers. Each apple was carefully examined for insect and disease injuries and the results tabulated. Scab injury was found on from 1 to 55 per cent of the fruit, curculio punctures on 10 to 87 per cent, codling moth on 0 to 3 per cent, etc. These results were so disappointing that some means of securing better pest control seemed imperative. The success of Massachusetts with the Spray Service and a "90% Clean Apple Club" suggested a line of attack. Consequently, such a program was undertaken.

Rhode Island, though it has five counties, is divided into three county agent districts. Most of the fruit is in the northern section. The county agents were consulted and a plan evolved whereby the Extension Horticulturist would prepare a series of letters calling attention to the need of better pest control and suggesting enrollment for the spray service on cards which were enclosed. These cards were returned to the county agents. The sign up card requested information as to size of orchard, principal varieties, type of sprayer, number of sprays applied last year, worst pests, etc., in addition to name, address and telephone number. The cooperators were immediately sent a spray program covering in a general way the spray season.

Scabby leaves were collected and examined at the college and weather reports were secured from the U. S. Weather Bureau in Providence. When the proper stage of development for spraying was noted, spray notices were sent by mail, telephone messages were relayed, and a radio announcement was given over two of the Providence stations. Later in the season the county agents and the Extension Horticulturist kept close watch of insect development and sent appropriate spray notices to cooperators.

In this first year over 200 fruit growers controlling 49 per cent of all bearing and non-bearing trees in the fruit section were enrolled. A total of eight sprays were recommended for the more susceptible varieties.

The middle of August, cards were sent to growers on which they might register a request for a check up for the so-called "90% Clean Apple Club". Membership in this club was offered growers who met certain conditions. The block of trees concerned must be one of the "New England Seven" varieties (Baldwin, McIntosh, R. I. Greening, Northern Spy, Gravenstein, Wealthy, Delicious), must have a crop of at least 300 bushels, thinning must have been stopped by August 1, and finally, the fruit must be at least 90 per cent free from preventable insect and disease injury. These requirements are high, but a surprisingly large number of growers succeeded in qualifying.

The checking for the club was done by the Extension Horticulturist and County Agent. Five trees located scatteringly throughout the orchard were selected. One hundred apples were carefully examined from each tree, care being taken to include all of the fruits on a given branch and to include branches on four sides and at different levels in the tree. In some cases the fruit was picked, while in others they were examined in place. One man on a ladder or in the tree called out the injuries found, which the other recorded.

At the end of the season the record was sent to the grower with suggestions for better control. At the annual meeting of the Rhode Island Fruit Growers' Association a certificate of membership, printed on parchment paper, was awarded to the growers qualifying for the club. The Fruit Growers' Association voted approval of both spray service and the "90% Clean Apple Club" and urged their continuance.

Nineteen orchards were checked and nine growers made 90 per cent or better on the blocks entered in competition. Considering the poor pest control in 1929 and the number of growers in the territory, this record was considered very satisfactory.

In 1931, 213 growers including most of those enrolled in 1930, again enrolled in the spray service. Since it was decided that card and radio notices were sufficient, the telephone messages were discontinued. Scab development was such this year that the pre-pink spray was omitted. Growers following our advice secured as good control as those applying this extra spray. The saving in material costs and time made the use of the spray service very valuable.

This year 17 blocks of fruit were finally checked for the 90% Clean Apple Club. If a block was obviously too low, no check was made. Of these 17, ten blocks, owned by eight growers, made 90 per cent or better. Five growers made the grade for the second year.

In one orchard of Gravenstein the check up gave some interesting light on the importance of environment on curculio control. A tree next to a stone wall and an adjoining bit of brush land had 80 per cent of the fruit stung by curculio, while the tenth tree showed only 12 per cent injury. All had received the same careful spraying.

In 1932 less effort was made to secure sign up cards. Only one card was sent out and no follow-up work was done. Growers knew that spray notices would be given out at the time of the regular radio program and so did not need to sign. In spite of this, 119 growers did send in cards. Again it was deemed safe to leave out the early scab spray.

Eleven different growers succeeded in passing a preliminary check on quality and were officially checked for 90% Clean Apple Club membership. Ten growers made the grade on 13 blocks of fruit.

One grower who made the club the first year and missed by a fraction the second, came back with one of the highest control records.

The Extension Horticulturist was on leave of absence during the 1933 spray season but the spray service was carried on by the agents, who by this time had come to understand fully the necessary technique. Eighty-eight growers were enrolled in two districts and notices sent to an additional 91 large and small growers in the third section.

This year a new spray program was devised by the Extension Horticulturist, cutting costs to the minimum and eliminating late applications to get away, in so far as possible, from the residue problem. In spite of this reduction to five applications, ten growers were so close to the 90 per cent grade that official checking was done. Six growers made the grade on 12 blocks of fruit. For the first time three growers made the grade on three varieties.

The spray service has become a regular part of our program and although the emphasis will probably be shifted this next year, service will be given by radio broadcasts, circular letters, etc. We have received many letters of appreciation for the service.

The "90% Clean Apple Club" idea worked very well as a means of checking on results, stimulating competition, and rewarding excellent work in pest control.

The Operations of the 90% Clean Apple Club in New Hampshire

By C. O. Rawlings, *University of New Hampshire, Durham, N. H.*

THE 90% Clean Apple Club of New Hampshire was organized by the Extension Service of that state in 1929. The object of the Club was to demonstrate that a crop of apples could be grown under practical commercial conditions such that 90 per cent of the entire crop would meet the requirements of New Hampshire Fancy grade with respect to insect and disease blemishes.

The rules are that any grower in the state who has a crop of 300 bushels or more of McIntosh, Baldwin, Northern Spy, Gravenstein, Wealthy, Delicious, or Rhode Island Greening, and has kept a spray record on that variety is eligible to enter the Club. The fruit grower may enter one or all of these varieties. All trees on the farm of the variety entered are subject to inspection. Though the fruit of a single tree, may be seriously damaged by pests the orchard is not disqualified; its fruit is prorated with the rest of the crop. If 90 per cent of the fruit is found on inspection to meet the requirements of New Hampshire Fancy grade for insect and disease blemishes, the variety is then said to meet the requirements of the Club and a certificate of merit is presented to the grower. Membership in the club therefore is not a certification of a grade, because several other factors such as size, color, and limb rub are not considered in making the inspections.

The County Agents announce the launching of the Club and notify the growers of the rules by means of circular letters and news stories. Growers expecting to enter their orchards notify the County Agent, who then sends them suitable forms for keeping the spray records. The forms provide space for recording of the date, the hours of spraying, the materials, formulae, the number of tanks used, the variety, the block sprayed, the number of workmen and horses, and the spray application. Certain other records regarding the specifications of the sprayer and the procedure of spraying are secured. At the time of the inspection, the spray records are collected and notes made of growth conditions of the orchard or any abnormality that is readily apparent.

The inspections are made by the County Agent and the Extension Horticulturist together, beginning the latter part of August. Counts are made of the fruit on the trees, using mechanical tallies; on one is recorded the good fruits and on the other the number of fruits below the standard. Trees for the counts are chosen at random throughout the orchard. No hard and fast rule is used as to how many fruits shall be counted on each tree or from which side they shall be selected. The procedure is to take fruits from the top to the bottom of the tree in a pie-slice, counting all apples in the section. Samples of ten apples each are taken at random from under trees throughout the orchard. These apples are cut in half horizontally and the number clean and the number infested with apple maggot is recorded. The

sampling is continued until the inspector is satisfied that the orchard is either qualified or not.

The blemishes checked are those made by insects or diseases for which there is an adequate control measure. Counts are likewise made of blemishes that are caused by improper spraying such as calyx injury by arsenic, or severe russeting, if they exceed the grade tolerance. It is the general practice to notify the grower at once following the inspection whether or not his orchard has met the requirements. Frequently he is present during the inspection.

The size of crop in these orchards varies from 300 bushels to 16,000 bushels. They are located in practically every fruit-growing section of the state on various types of soils and elevations. McIntosh leads in the number of bushels entered and meeting the requirements. Baldwin stands second. The total number of bushels has increased until in 1933 there were 161,700 bushels of all varieties entered, of which a little over 60 per cent grown by 26 orchardists met the requirements. The fruit entered was grown by 36 fruit men averaging over 4,500 bushels per grower. The names of the entries are not revealed to the press, but news stories of the winners are furnished to nearly all state papers.

The data taken during the inspection is analyzed later to determine the effectiveness of the spraying operations. Figures from all orchards, including those rejected, are used. The spray applications are plotted on a graph having the horizontal axis laid off in the days of the month and the vertical axis the different fields or blocks and using a separate graph for each variety of apple. The sprays are drawn in the graph using different colors to represent different spray materials. The rainfall and temperature for the spray season are plotted along the bottom of the chart. Such a graph shows at a glance the number of days between the sprays, the different spray treatments of each block, the rainfall and temperature.

A few examples may show how the records are used to further the extension work. In 1931, a very bad scab year in New Hampshire, a graph showing the spray applications to McIntosh, prepared as described above from records secured in connection with the 90% Clean Apple Club, brought out clearly the importance of timely spraying. Data on two blocks of McIntosh owned by the same man had sprayed alike in all applications up to and including calyx showed that a lapse of 6 days at the first cover spray, during which a heavy rain period occurred, made the difference between a very clean crop in one orchard and a fairly heavy scab infection in the delayed-cover block. The latter orchard received additional applications of dust throughout the rest of the season and had been the cleaner of the two blocks the year before. The on-time cover sprayed block had no further spray or dust applications after the first cover.

In another orchard in 1931, there was considerable russet on the Baldwins. Examination of the graph showed that the last two summer sprays had been applied during the two hottest periods of the season, when the temperatures were above 90 degrees F.

The graphs of the spray records, used in fruit meetings to show the

importance of timely spraying, constitute the most effective teaching material we have. Growers learn from these what the spraying practices of the 90% Club members have been. When a fruit grower sees this material and knows that it was gathered in commercial orchards, he is in a frame of mind to believe what is being said.

The spray records are used in many other ways. For example, last spring when the strict tolerance on lead residue was promulgated by the Federal Food and Drug Administration the records were examined to see whether calcium arsenate had been used. Some of the 90% Club men had used it and according to the orchard notes fairly successfully. It had also been used experimentally in the college orchards and with certain precautions, satisfactorily. The results of the experimental use of the material together with the orchardists' use of it gave a practical background for recommending it in 1933, resulting in many growers trying it.

The data collected with reference to spray equipment and how used is likewise summarized and presented at the fruit meetings. Some of the orchardists have varied their spraying operations by spraying at night, spraying with the wind, riding the tank, using multiple nozzles instead of guns, spraying when the weather is wet and foggy, using new materials, dusting and testing many combinations. It is often difficult for the individual grower to evaluate these different methods. However, if he can bring his crop through the season in such condition that the quality will meet the requirements of the 90% Club, he then has a standard by which to measure the relative effectiveness of the procedure. Thus it has been demonstrated that fruit growers in New Hampshire can ride the tank, spray with multiple nozzles with the wind and get good control of scab even in a very bad year such as 1931. Most of the 90% members have demonstrated for themselves that they cannot in spraying skip the top of the tree and bring through a crop that will meet the standards.

Pomologists have long known that the environment of an orchard influences the population of certain insects within the orchard. Apple maggot, the most serious insect pest of New Hampshire apples, is one of them. It breeds in the many wild seedlings and neglected apple trees scattered throughout the state.

In 1932, the orchards entered in the 90% Club were classified as having a "good", "fair", or "bad" environment. Two such classifications were made of each orchard, one for the conditions existing outside of the orchard and the other for within it. The environments were so classified to determine whether they were influencing the degree of infestation in the orchard. An environment outside the orchard was considered bad if within 300 yards of the orchard there were several old neglected or wild apple trees. The inside environment was considered bad if it contained susceptible varieties such as Wealthy, Red Astrachan, or Porter. If no neglected trees were nearby the outside environment was considered good; if there were no susceptible ones inside the orchard, it was considered to possess a good internal environment. Of those who were in the 90% Club, only one had a bad outside environment, the environment in that

case being an old neglected orchard at one end of the block. However in this exception, the old orchard is in a pasture where cattle are kept. In 1933, the Baldwins in this orchard failed to meet the requirements because of too much railroad worm. On the other hand, several orchards having a bad internal environment met the Club standards. This leads us to consider it extremely important to destroy trees near the orchard in which this pest may breed.

Thus, although the 90% Club was first organized to demonstrate that quality fruit could be grown, it has gradually become useful in other ways. It is a means by which the fruit grower can know the pests in his orchard and their relative abundance. It stimulates the interest of his workmen to be more careful of their spraying. Sometimes it has assisted in the sale of his fruit. Since it embodies competition it stimulates his incentive to produce fruit that will meet the requirements. It is a way by which he can evaluate his methods as compared with those of other fruit growers.

It is a most valuable aid to the Extension forces for the surveys furnish a check-up of the pests present and of the effectiveness of the recommendations and consequently is a basis on which to formulate the pest control program. The surveys made in connection with it provide a practical background to the recommendations which increases growers' confidence in them. The 90% Club, through the inspections and records, gives the Extension workers a more intimate knowledge of the orchards. Knowing the orchards enables them to advise the grower more definitely and more convincingly than from general information as to what are his particular orchard troubles.

Progress in Horticultural Science

By LAURENZ GREENE, *Purdue University, Lafayette, Ind.*

PROGRESS in science was emphasized in the celebration of "A Century of Progress" in Chicago during the summer of 1933. The contrasts shown there were in a large measure the product of scientific developments. The exposition made of this a season for the recording of achievements in many branches of science. A brief survey of advances in horticultural science may provide a background for a more rational program of procedure and organization of research during this time of economic stress and change.

Nearly 100 years ago Dr. John Lindley of England recognized a science of horticulture in these words: "The art of horticulture comprehends whatever concerns the mere manner of executing the operations connected with cultivation, multiplication, and amelioration; the science explains the reasons upon which practice is based." Horticulturists of today are not satisfied merely to explain principles but strive to establish practice upon a scientific basis in order that losses may be avoided and profits enhanced.

However, definitions should not cloud thinking nor confine it to narrow lines of demarkation.

The fine distinctions of science are man-made, not plant-made. Dean Bailey has defined horticulture as—"The growing of fruits, vegetables, or flowers for pleasure or profit." Accordingly it deals with plants and plant products. It properly follows those products through all the processes and channels of trade to the consumer.

Nor is horticulture a study of the adaptations of genera and species alone, for, in the last analysis, it deals with the responses of varieties and strains.

Whatever adds to the sum total of knowledge of horticultural plants and helps to explain their behavior under the varying conditions of culture may be regarded as a part of horticultural science.

Whether the results be from research by chemist, botanist, economist, or horticulturist is of small import in summing up progress.

The art of horticulture was well developed 100 years ago. Grafting, pruning, greenhouse forcing, crossing, and hybridizing, the use of natural manures, and other practices were quite similar to those of today. Interest in commercial horticulture was developing, but horticulture of that time was largely a matter of pleasure, rather than of profit. Its advancement was largely the interest of gentlemen with some leisure.

In America several of the older societies were functioning, and exhibits of meritorious specimens of plants, flowers, and fruits were held. The Botanic Gardens of Bartran and of Prince were already of world renown. Exchanges of fruits, seeds, and propagating wood with European horticulturists were not uncommon. But, in the words of Coxe, horticulturists in this Country were largely dependent upon Europe for the science underlying practice.

That science was largely botanical with an awakening interest in the applications of chemistry. Botanical description and classification were of utmost importance in listing those varieties of food and ornamental plants that would withstand the rigors of the climate in the new world. "Vegetable Physiology," however, was being developed by the painstaking researches of such Europeans as Lindley, Knight, Von Mons, DeCandolle, and others. That this earlier science was having an influence upon horticultural practice is evidenced in the words of Dr. Lindley: "Indeed the enormous difference that exists between the skill of the present race of gardeners and their predecessors can only be ascribed to the general diffusion, that has taken place, of an acquaintance with some of the simpler facts of vegetable physiology."

Horticultural Science of the earlier years may be partially visualized by reference to some of the theories and practices of the time. The scientists were usually true horticulturists and had mastered the art of manipulation. Their laboratories were in their own gardens. These close students of plants saw clearly that constant changes were taking place in their cultivated plants and that this was contrary to the philosophy of the times, which decreed that species were fixed. Dr. Lindley, as late as 1831, stated that, "Philosophers are unacquainted with the reason why there should be any tendency to variation from the characters first stamped upon any species by nature." Lindley was a great admirer of Thomas Andrew Knight, and was familiar with his work and theories. Knight had written, 20 years earlier: "Nature appears to have made every species of esculent and fruit capable of endless change and probably, relative to the use of many, capable of endless improvement." Knight's recognition of these facts antedated the explanation by Darwin, by nearly half a century.

Von Mons of Holland was a producer of improved sorts of all kinds of horticultural plants, notably pears. He believed he could eliminate the "wildness" of plants by continually replanting several generations of seeds. He felt that at least five generations were necessary in the case of pears, while a lesser number would suffice in other cases. Theirs was not a belief in the transmission of "acquired characters" about which they knew little, for they expected these improved sorts to revert to the natural wild state under neglect. They also noted that seedlings from crosses were often more variable than those from selfed seed. They distinguished between crossing and hybridizing or "muling."

That the pollen of one variety might affect the quality of fruit of another was the commonly accepted fact. This had been proposed by Coxe earlier in the century.

Theories relative to the decline or running-out of varieties were matters of rather bitter controversy. Coxe had recognized that "varieties have their responsive periods of duration after which they languish and decline." The decline of asexually propagated plants, according to a theory advanced by Knight, was dependent upon the vigor of the original parent and the progeny would not flourish beyond

the natural life of the original plant. It was regretted by many writers that such a theory should have been advanced by so noted and respected a scientist. The evidence finally proved this theory to be false. In more recent years senility of clonal lines has been attributed to disease.

That ringing a branch caused an accumulation of food materials above the ring, causing flowering and fruitfulness, was a matter of record. Explanations were remarkably near those offered today.

The "vital force" of plants explained many unknown facts of the time. Philosophers ridiculed the idea, but these students of plants were confident that a vital force accounted for many things they could not understand. Lindley says, "The functions of the leaves are performed by means of the vital force of vegetation which we can not estimate or comprehend, assisted by the influence of an external agent, the nature of whose action may be understood from its effects. That agent is solar light"; and, "By their vital forces plants appear to decompose water independently of the action of light."

Lindley also recorded the efficiency of light in the decomposition of carbonic acid and water, the formation of "vegetable alkaloids, the extrication of nitrogen, and probably other causes as yet unknown." "It is the property of solar light when striking the leaf of a plant either directly or indirectly to cause first, a decomposition of carbonic acid; second, an extrication of oxygen; and third, insensible perspiration." However, Leibig dissented from these views and argued that "exhalation of carbonic acid is as unconnected with the process of assimilation and with the life of the plant as is the absorption of oxygen."

Garreau, a French scientist, had demonstrated that the two surfaces of the leaf perspired at different rates, and rightly attributed this to stomatal differences.

The effects of various colored lights were studied in France and England. In 1847, Mr. Hunt covered a palm house at Kew Gardens with green glass. The conclusions drawn were that white light, which is natural to plants is "that which is best adapted to their constitution."

The effects of moonlight were carefully studied in Italy and it was discovered that in plants of "delicate organization," like the sensitive plant, certain motions were noted as soon as the plants were exposed to the lunar rays.

DeCandolle succeeded in making crocuses expand by lamp light and Dr. Winn suggested that "the oxy-hydrogen lamp may be made subservient to horticulture in the long dark days of winter."

The circulation of plant sap was perhaps less controversial then than today. In fact, the theories advanced by those earlier workers have stout defenders still. Their theories of digestion and assimilation were subjected to doubt fifty years later. Barry speaks of the formation of cambium from the crude sap and quotes Schleiden to the effect that, "As soon as it [the sap] enters the roots it becomes assimilated and fit for the production of new cells and that it passes upward forming new wood or cells by a chemical process."

The failure of plants to bloom when transferred from one latitude to another was attributed by Hovey to failure of the petals properly to reflect the sun's rays to the pistil and thus warm it. The preponderance of white flowers in colder climates was, in his opinion, ample proof of this theory. Day length effects were discovered only very recently.

Attempts were made to perpetuate the many double forms of flowers found in gardens. James Monro of England claimed to have produced double stocks in a single variety by reducing the number of seed pods per spike. The French relied upon a debilitating process to produce the same effect, contending that seed planted immediately would produce only single flowers, but that the same seed planted three or four years later would produce double flowers. Recent work confirms the theory of Gaertner, who contended that to get double stock flowers the mother plant at least must be double. As has been shown recently, doubleness is a hereditary factor.

Time permits the mention of only a few outstanding facts and discoveries that have profoundly affected both the art and science of horticulture during the century.

Leibig's discoveries led to many trials of fertilizers, but, in the main, plants on soils of high fertility supplied with natural manures did not respond, and so the use of chemical fertilizers with the varied problems of research involved came late in the century, with much of the accomplishment recorded in the proceedings of this society, since 1903. By 1850 many chemical analyses of plants had been made. David Christy published in 1852 analyses of apple, peach, and nut trees, rose bushes, strawberries, and apple fruits.

Darwin's papers, beginning in 1858, explained much of the variation horticulturists had noted earlier and increased interest in the improvement of horticultural varieties. These theories provided a surer basis for research and "amelioration."

The invention of the compression type of refrigeration machine in 1855 and the shipments of fruits under refrigeration beginning in 1866 provided for an expansion of horticultural industries which opened a new field of research. The contributions of that research have made possible the transportation of horticultural products around the world.

The value of science in developing practice is well illustrated in the canning industry. The art of canning by sterilization was known from the publication of Appert's paper in 1811, but the great development of the industry followed the explanatory scientific work of Pasteur about 1860. It is of interest to note that Leibig stoutly opposed Pasteur in his microbe theory, maintaining that chemical action rather than bacterial action was responsible for the spoiling of foods. The preservation of horticultural food products in cans and other containers greatly stimulated commercial production, and provided research problems of production and processing, many of which are still unsolved.

Thomas Meehan, through his publication, "The Gardener's Monthly," did much to popularize the application of science to horti-

cultural practice during the thirty years of that journal, from 1859 to 1889.

The Land Grant College Act of war times made possible a great stimulation in horticultural research and with the Hatch Act of 1887 provided for state support of research workers.

The development of spraying methods, beginning in the seventies, made possible the control of insect and disease pests and added research problems as to control methods and the toxic effects of spraying compounds upon horticultural plants.

The rediscovery of Mendel's work about 1900 stimulated a decade of breeding of horticultural plants which continues with less publicity to the present day. The practical progress in that field of horticultural endeavor is bringing pleasure and profit to amateurs and commercial horticulturists in ever-increasing numbers.

The actual progress of horticultural science during the past 30 years is well set forth in the published Proceedings of this society. Little time need be devoted to that recent history. No one can review these publications without a profound conviction of progress.

Outstanding contributions of horticultural science which mark progress during the past century would include dwarfing, which was unknown at the beginning of the century; the effects of respiration in storage; the relationships between irrigation and sugar content of fruits; shading and earlier flowering; photoperiodism; carbon and nitrogen relationships; nutrition; fertilizers and shape of root crops; hardening and chemical composition; vitamin content of affected by culture; the effect of ringing on carbon assimilation; fruit bud formation and fruit setting; sterility and its relationship to fruitfulness; hydrogen ion effects upon color of flowers; food absorption and productiveness; soil moisture relations; freezing effects on plant tissue; chlorosis; plant food deficiencies; and a host of others.

Many of the problems of research have been undertaken to meet the needs of rapidly expanding industries spreading to new and distant locations with widely varying conditions. These same industries made possible greater governmental support. Without that support and the incentive which they also supplied, the record would be much less extensive. Commercial horticulture has been the great motivating force among scientific investigators for half a century. Horticultural Science, however, has other functions than to serve commerce alone. The millions of enthusiastic amateurs, who grow plants for the mere joy of it are entitled to the service which the scientist can render.

Much of the progress in Horticultural science has been accomplished in attempts to determine the extent to which the discoveries in other sciences could be adapted to horticultural practice. The response of plants to treatments under controlled conditions is of little practical value to horticulture until the scientific principle involved has been applied under the conditions of the orchard, the garden, or the greenhouse. The horticulturist renders a real service in making practical application of fundamental scientific facts. For many this will be the greatest service they will have the opportunity to render.

For others, basic discoveries will come from their research, as has been so often reported at the meetings of this organization. The greatest service will be rendered by bringing to bear all the scientific knowledge and technique possible upon the problems in hand. Research workers of the present and future have greater opportunities for service than had those of the past. The well-trained investigator can have a better understanding of the scientific explanations of responses of plants to different environmental influences. He should have a working knowledge of established practice in the particular field of horticultural endeavor to which he devotes his studies.

A striking similarity exists between many of the problems under investigation in 1833 and the research program of 1933. If progress seems slow to the uninitiated, it is due to a lack of appreciation of the intricate relationships that exist in biological organisms and the varying reactions of plants to many factors impossible of control under natural conditions. To the better informed, progress of knowledge relative to the form and function of horticultural plants and the effect of that knowledge upon practice is gratifying and holds promise of added accomplishment as new problems arise.

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